TEST OF A COMMUTATING RECTIFIER

BY

C. E. STRYKER

W. T. WATT

ARMOUR INSTITUTE OF TECHNOLOGY

1917

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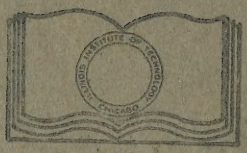

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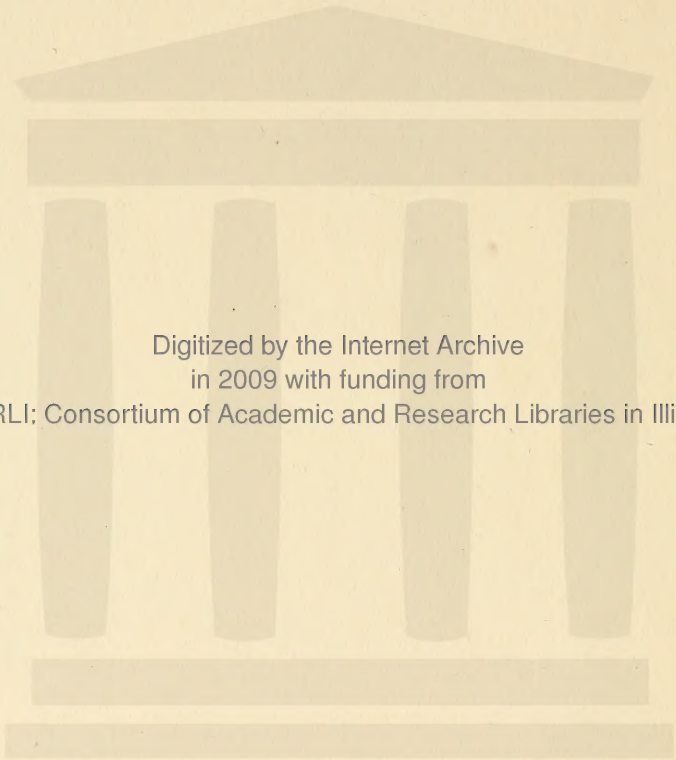

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A TEST OF A COMMUTATING RECTIFIER

A THESIS

PRESENTED BY

WILLIAM T. WATT AND CLINTON E. STRYKER

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

MAY 31, 1917

APPROVED:

E. H. Freeman
Professor of Electrical Engineering

H. M. Raymond
Dean of Engineering Studies

L. C. Morrin
Dean of Cultural Studies

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The authors desire to express their indebtedness to Professor Ernest Harrison Freeman for his invaluable assistance and untiring interest in the work undertaken.

They also wish to thank the Stahl Rectifier Company, and Mr. Frank D. Pearne, for their kindness in extending the use of the apparatus.

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-C. E. S.-

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FOREWORD.

The aim of this report is to make a study of a Commutating Rectifier, for the purpose of determining its various characteristics with special emphasis on the operating efficiency and commercial applicability.

It must be borne in mind that this type of apparatus has been developed by practical men and very little investigation and writing from a theoretical standpoint has been done. The report therefore contains several investigations as to the correct methods and instruments to be used, in order to obtain the desired results.

It is hoped that the results given in this report will be of some assistance to those conducting investigations along this line in the future.

Armour Institute of Technology

May 31st,1917. William T. Watt.

Clinton E.Stryker.

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INTRODUCTION.

The Commutating Rectifier is a device for rectifying alternating into a pulsating direct current, so as to permit its use for charging storage batteries. This result is accomplished by means of a commutator, driven by a synchronous motor, in conjunction with suitable transformers, relays, et cetera.

This investigation may be divided into the following general sections :

The Theory of Operation and the Construction of the Apparatus.

The Calibration of the Instruments.

A Study of the Correct Methods and Instruments To Be Used , In Order to Obtain the Desired Results.

The Determination of the Operating Characteristics of the Apparatus.

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The Discussion of the Commercial Applicability of the Device.

Considerable work was done with the oscillograph, in order to ascertain the actual wave shapes and phase relations of the currents and electro-motive forces.

The battery used throughout the tests was the 60-cell battery located in the Electrical Engineering Laboratories of the Institute. This battery is connected into two sets of 30 cells for charging, the normal charging rate being about 75 amperes at 70 volts. Current was supplied to the rectifier at 220 volts, from a 30 K.W. 60 Cycle, 3 Phase, 1100 Volt Western Electric Generator, through the medium of three 5 K.V.A. Westinghouse 25 Cycle, 1100: 220 Volt Transformers connected in parallel across one phase of the generator. It might be noted that the generator gave an approximate sine wave of e.m.f.

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It is believed that the work was carried out with sufficient accuracy to render the results fairly reliable. Throughout this report mention will be made of various safeguards taken against error and the extent of the influence of various factors on the results obtained.

The Stahl Commutating Rectifier.

TEST OF A COMMUTATING REOTIFIER.

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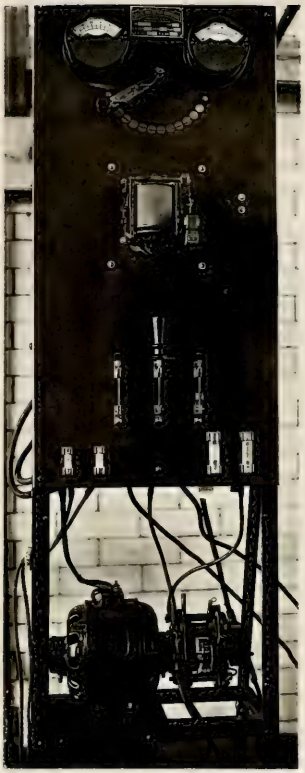
Figure 1.



The Stahl Commutating Rectifier.

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THEORY AND CONSTRUCTION OF APPARATUS.

The basic principle of the commutating rectifier is that of a synchronous motor driving a commutator so constructed as to reverse the direction of current flow every half cycle, giving rise to a pulsating direct current.

This construction will be more easily seen with the aid of the accompanying drawing. the motor used is a four-pole machine of the segmental type of single phase induction motor. This motor will run at synchronous speed until overloaded, by virtue of the fact that its secondary winding is divided into four well defined sections, which sections tend to fall directly under the poles at each half cycle. The motor is brought up to speed as a form of repulsion motor, the change in connections being made by a centrifugal device on the motor shaft.

Mounted on the motor shaft are two collector rings and an eight segment commutator,

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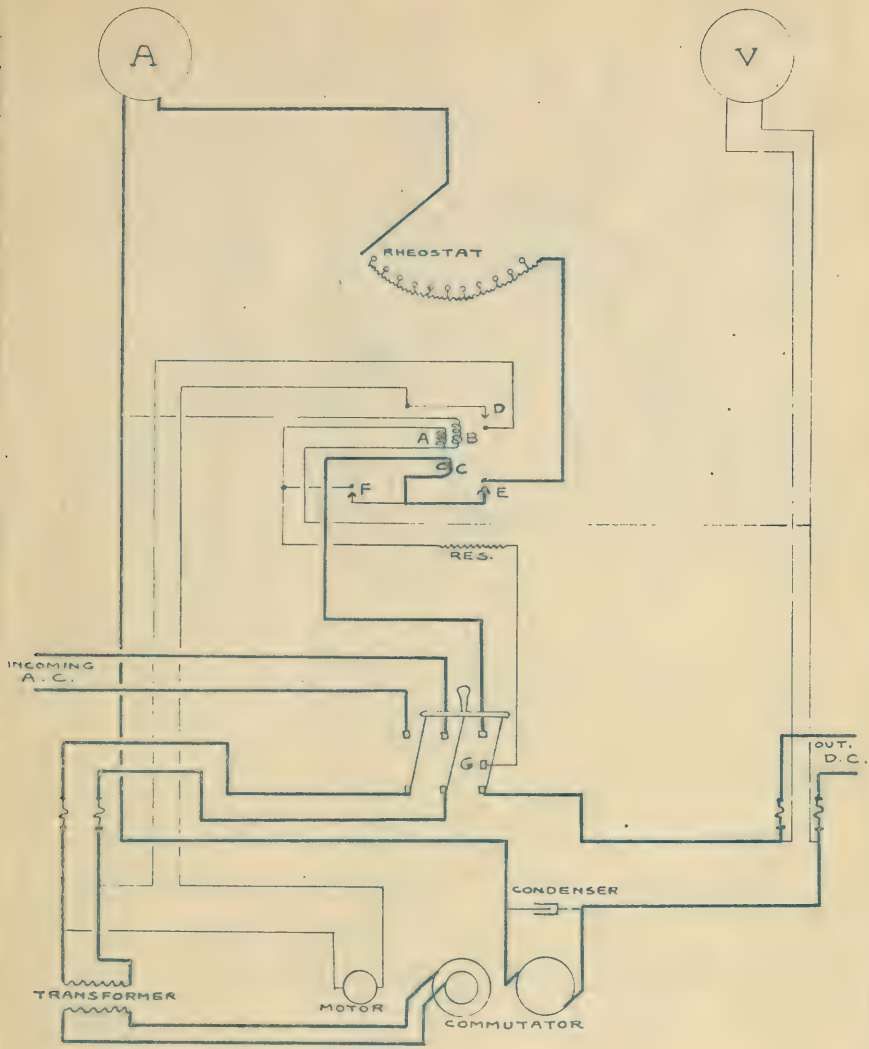

GENERAL CONNECTIONS

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FIGURE 3

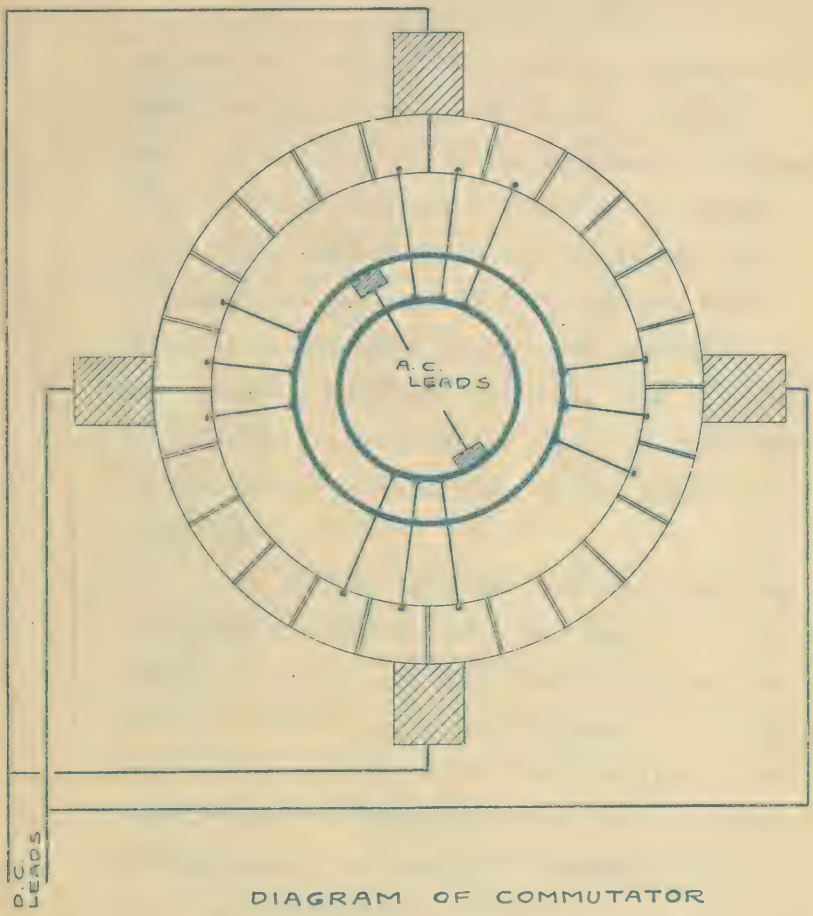

DIAGRAM OF COMMUTATOR

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connected as shown in the diagram. As the motor makes one revolution in two cycles, (being a four-pole machine) the collector rings will change polarity four times per revolution. The commutator is so connected, as can be seen from the diagram, that the collector ring of the right polarity is connected through the commutator to the correct direct current brush. The relations of the currents and e.m.f!s resulting from this operation will be made clear by the oscillograms shown later.

It will be seen that the commutator has half of its segments dead. The reason for this is that, primarily, some room must be allowed for the brush width, in order to prevent short-circuiting, and, secondly, on the lower portion of the e.m.f. wave, the impressed e.m.f. is less than that of the battery, so that it is necessary to open the circuit on this portion of the wave, in order to prevent the battery from discharging . The reason for subdividing the commutator segments is

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to reduce eddy current losses. For the same reason, the collector rings are made of high resistance brass.

The remaining apparatus consists of a 3 K.W.- 220:75.6 ratio transformer, an adjustable iron grid rheostat, a voltmeter and ammeter of the D'Arsonval type, the relay and the fuses and switch. The incoming alternating current flows into two circuits; that of the motor, and the power circuit.

In the power circuit the current flows into the teansformer. From the secondary of the transformer it flows to the collector rings of the rectifier. The direct current is taken from the commutator and flows through a circuit comprising the battery, the coil (C) and the contact (E) of the relay, the rheostat and the ammeter. The voltmeter is connected directly across the battery terminals.

In operation, the rheostat is placed on the first position and the switch closed. The

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The remaining apparatus consists of a 3 K.W.- 230:75.8 ratio transformer, an adjustable iron grid rheostat, a voltmeter and ammeter of the D'Arsonval type, the relay and the fuses and switch. The incoming alternating current flows into two circuits; that of the motor, and the power circuit.

In the power circuit the current flows into the transformer. From the secondary of the transformer it flows to the collector rings of the rectifier. The direct current is taken from the commutator and flows through a circuit comprising the battery, the coil (D) and the contact (E) of the relay, the rheostat and the ammeter. The voltmeter is connected directly across the battery terminals.

In operation, the rheostat is placed on the first position and the switch closed. The

extra contact (G) on the switch closed first, completing a circuit from the battery through the resistance and the relay coil (A). This coil exerts a magnetic pull sufficient to close the contact (D), which has a weak spring, but not sufficient to close (E), which has a strong spring. Upon the closing of the contact (D), the motor circuit is closed up to the main switch. When the remaining contacts of the switch are closed the motor starts, causing an e.m.f. to exist across the brushes of the commutator, and a current to flow through the coil (B). The coil (A) is now getting current through the contact (F) which cuts the resistance out of circuit. If the polarity of the e.m.f. at the brushes is correct, the cumulative action of coils (A) and (B) will cause the contact (E) to close, completing the charging circuit.

If the polarity is incorrect, however, the coils (A) and (B) will oppose each other, causing

coils (Y) and (H) will oppose each other, causing the charging current.

If the polarity is incorrect, however, the same current will flow through the coils (Y) and (H) in the same direction, causing the cumulative action of coils (Y) and (H) will cause the contact (K) to close, completing the circuit of the e.m.f. at the purpose is secured, which cuts the resistance out of circuit. If the polarity of the e.m.f. at the purpose is correct, (Y) is now getting current through the contact (I) a current to flow through the coil (H). The coil (H) is now energized and attracts the armature, and closed the motor starts, causing an e.m.f. to When the remaining contacts of the switch are motor circuit is closed up to the main switch. closing. Upon the closing of the contact (D), the switch to close (K), which has a strong contact (H), which has a weak spring, but not sufficient to close the contact (D), the coil exerts a magnetic pull sufficient to close the the resistance and the relay coil (A). This coil completing a circuit from the battery through extra contact (G) on the switch closed first,

(D) to open, and preventing (E) from closing. This lets the motor slow down until it "slips a pole", correcting the polarity and causing both contacts to close, and charging to start.

The contact (F) is so arranged as to open when contact (E) is closed. Its purpose is to insert the resistance into the circuit of coil (A) so as to decrease the current and heating. The heavy current used in staring is not needed after the circuit is closed through contact (E), as the coil (C) now adds to the field produced by the other coils. The coil (C) is in series with the battery and so wound as to increase the pull while the current flows normally. If, however, the battery should for any reason feed back on the line, the flux from coil (C) would neutralize that from the other coils and cause the contacts to open and the machine to stop.

In order to obtain a sufficiently steady current from the brushes to close the contacts, it has been found necessary to place a condenser

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across the brushes. This, of course, produces a lagging discharge current that holds the current supplied to the coil more nearly constant.

The purpose of the extra contact (G) is to insure that the motor will start immediately upon closing the main switch. If the contact (D) was not already closed when the main switch contacts were closed, the commutator might be in such a position as to impress an alternating e.m.f. on the coil (B), which would effectually prevent either of the contacts from closing and make it impossible for the device to operate. It might be noted here that, once the motor is turning, it is practically impossible not to have a period of direct current long enough to close the contacts and start operation.

From the above description, it is apparent that the machine is entirely automatic in operation, and may be trusted to the use of the average garage helper. The reverse current feature removes all

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TEST OF A COMMUTATING RECTIFIER.

Calibration of Instruments.

As is well known, measuring instruments, especially those of the soft-iron or dynamometer types, cannot be depended on to hold their calibrations indefinitely. For this reason, all meters used in this report were calibrated against a standard cell by means of a potentiometer and shunts of Otto Wolff make. The procedure followed is briefly outlined below.

The D.C. voltmeter and ammeter and the standard meters were checked directly with the potentiometer. It was believed that the standard meters would hold their calibrations with sufficient accuracy, as they are very little used, so that all later checks were made against them and corrections applied on their errors.

The alternating current meters were calibrated on direct current, taking reversed readings, and obtaining a mean. The wattmeters were calibrated by impressing a potential on their

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The alternating current meters were calibrated by impressing a potential on their binge, and obtaining a mean. The meters were rated on direct current, having reversed rem-

pressure coils, and allowing a low voltage current to flow through their current coils.

The calibration curves of all meters are appended herewith, and it might be noted that all the meters held closely to the errors shown by these curves throughout the tests, as was shown by repeated checks against the standard meters.

The readings given throughout this report are the correct values, and not the indicated values, unless specifically stated otherwise.

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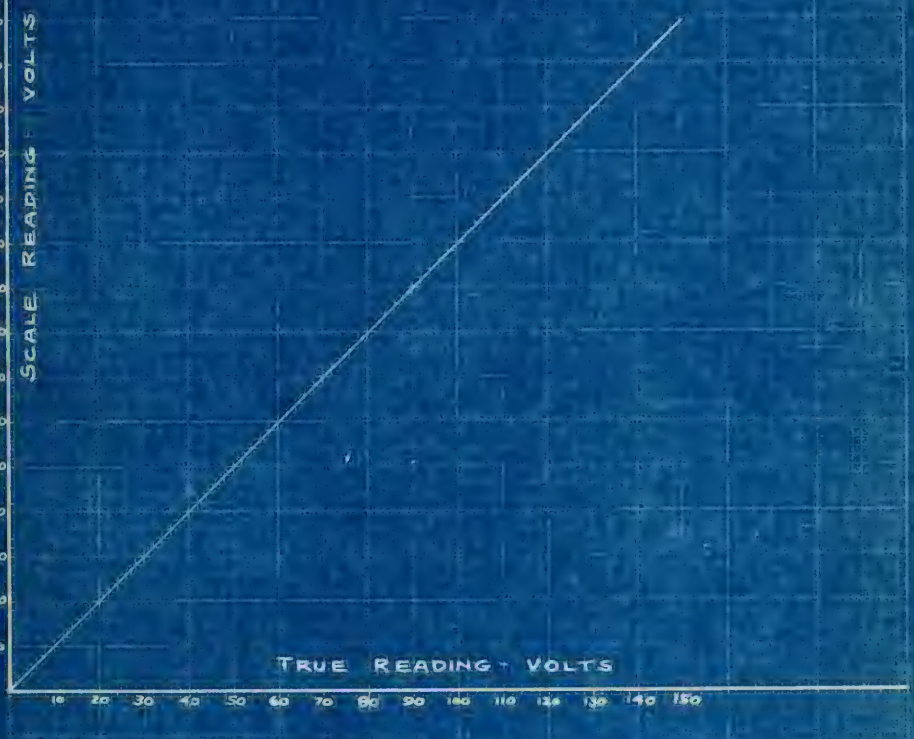
FIGURE 4



CALIBRATION CURVE FOR LABORATORY STANDARD VOLTMETER ON 150 SCALE

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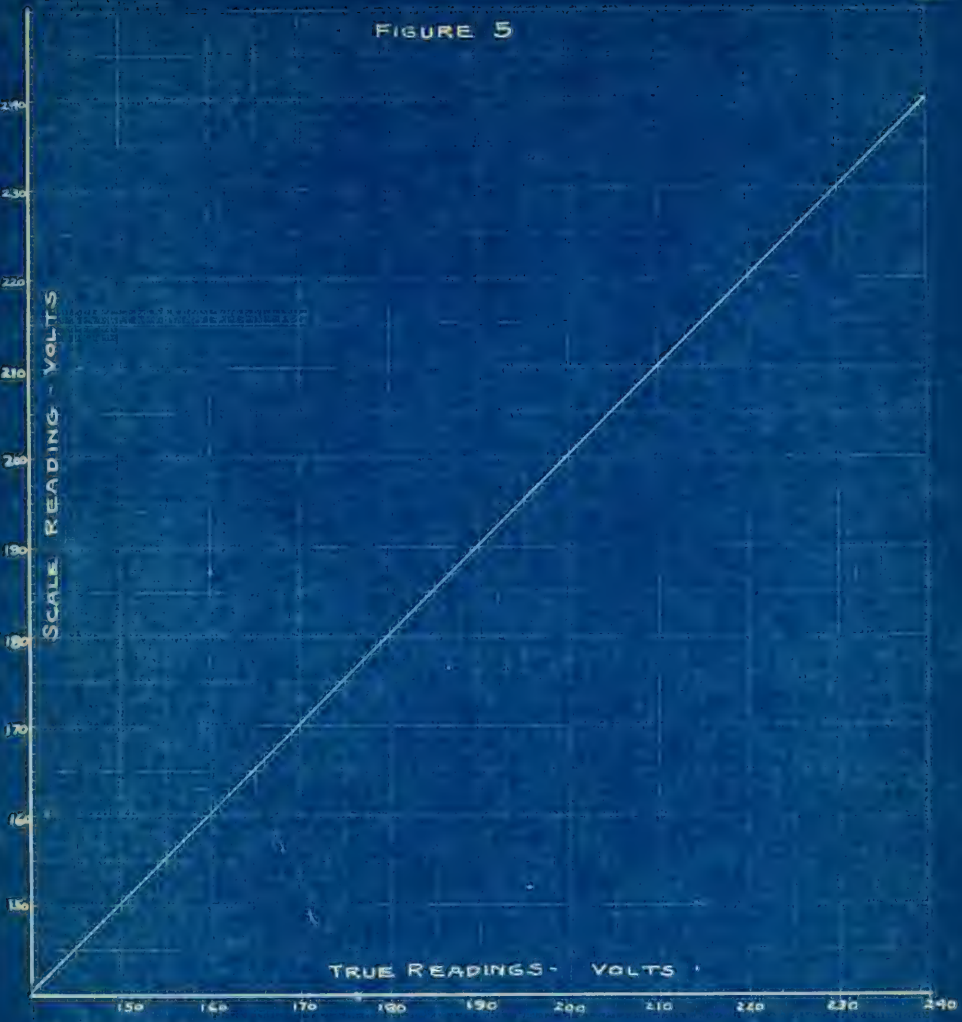
FIGURE 5



CALIBRATION CURVE FOR LABORATORY STANDARD VOLTMETER ON 300 SCALE

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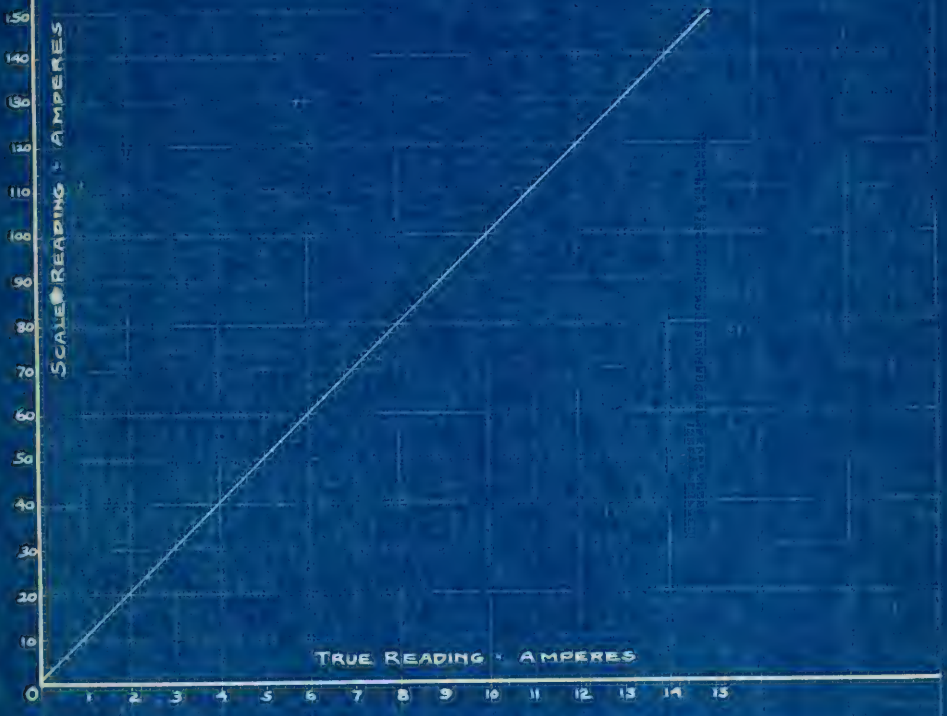
FIGURE 6



CALIBRATION CURVE FOR LABORATORY STANDARD AMMETER ON (0-15) SCALE

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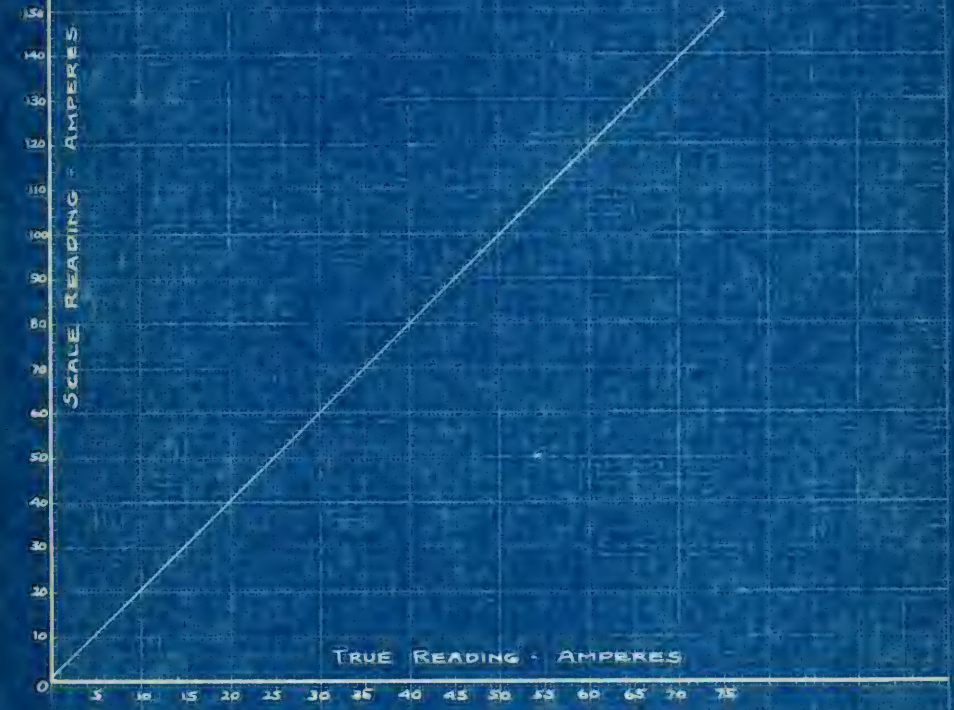
TABLE 7



CALIBRATION CURVE FOR LABORATORY STANDARD AMMETER ON (0-75) SCALE.

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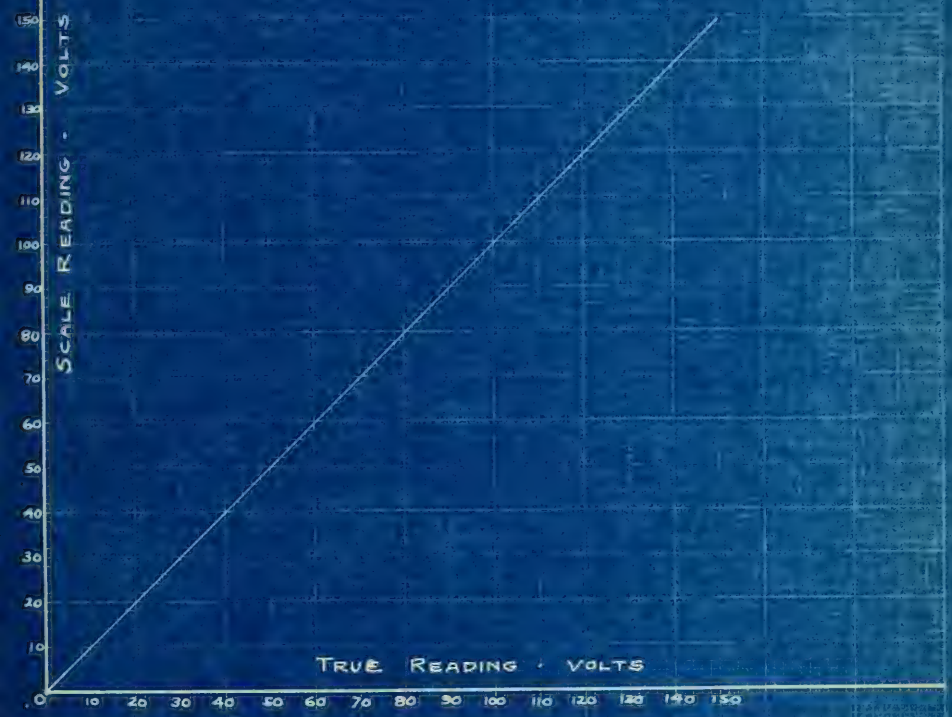
C.E. STRYKER

TABLE 8.



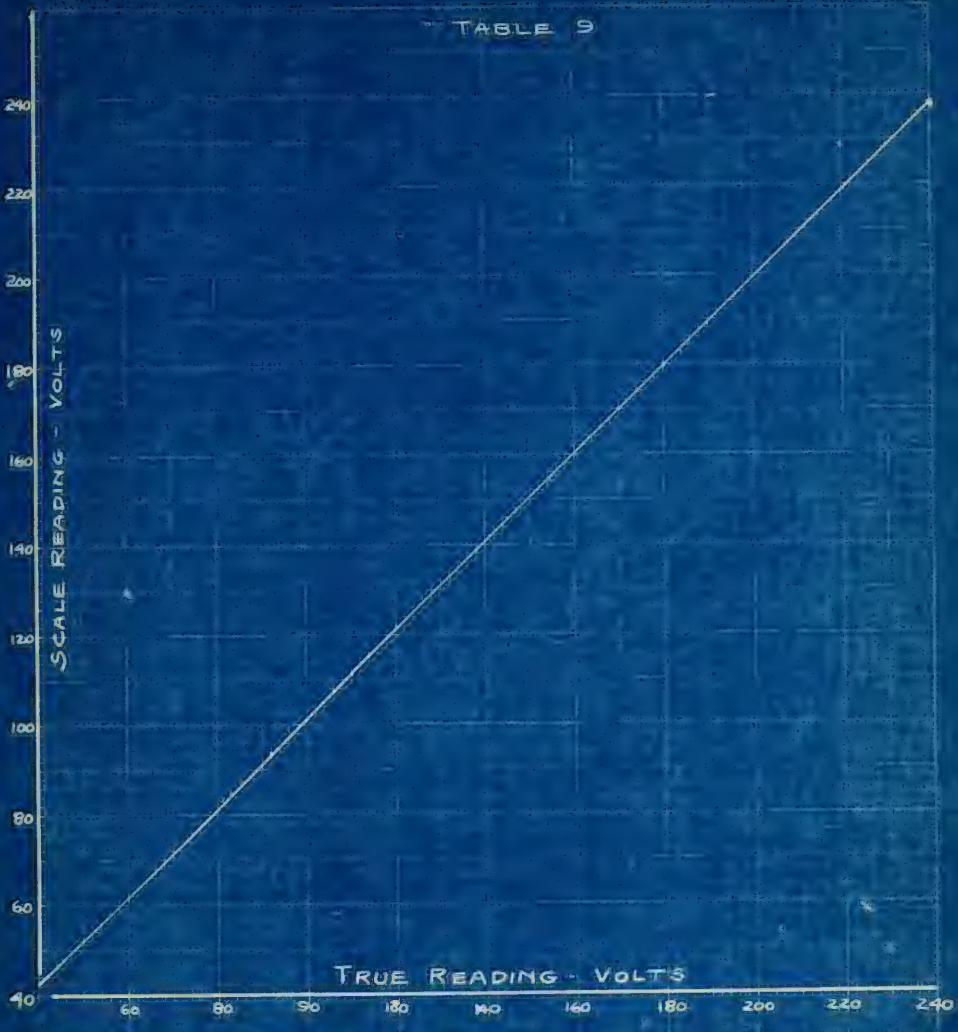
CALIBRATION CURVE FOR A (0-150) D.C.
WESTON VOLTMETER # 4403

TEST OF A COMMUTATING RECTIFIER

THESIS 1917
W. T. WATT

E. E. COURSE
C. E. STRYKER.

TABLE 9



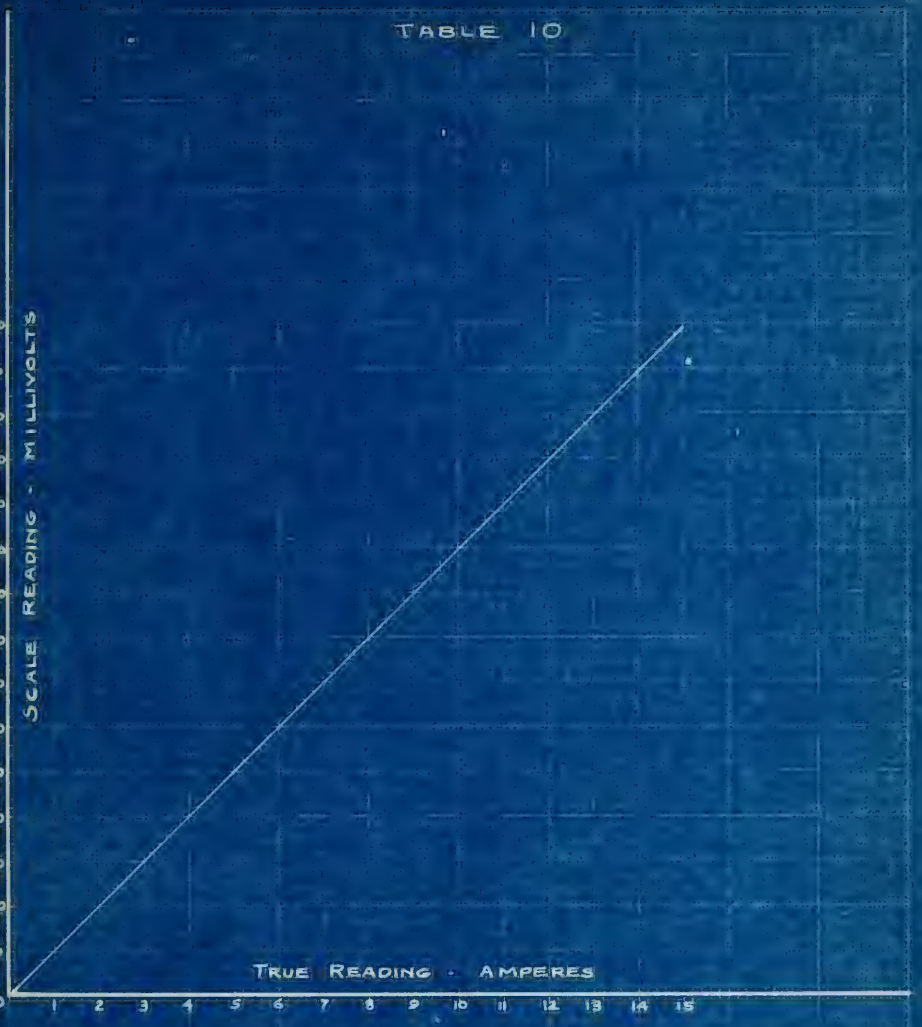
CALIBRATION CURVE OF A
WESTON A.C. VOLTMETER
#5246, RANGE (0-250)

TEST OF A COMMUTATING RECTIFIER

THESIS 1917
W.T. WATT

E.E. COURSE
C.E. STRYKER

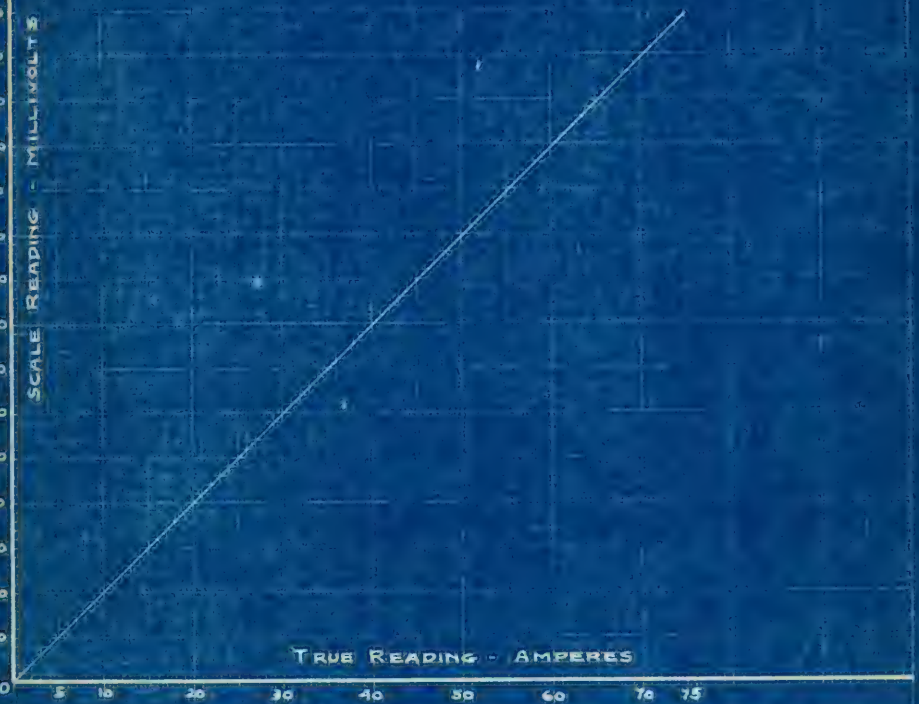
TABLE 10



CALIBRATION CURVE FOR A (0-150)
G.E. - MILLIVOLTMETER - TYPE D P # 198849
WITH G.E. - 15 AMPERE SHUNT # 209592

TEST OF A COMMUTATING RECTIFIER
THESIS 1917 E.E. COURSE
W.T. WATT C.E. STRYKER

FIGURE 11

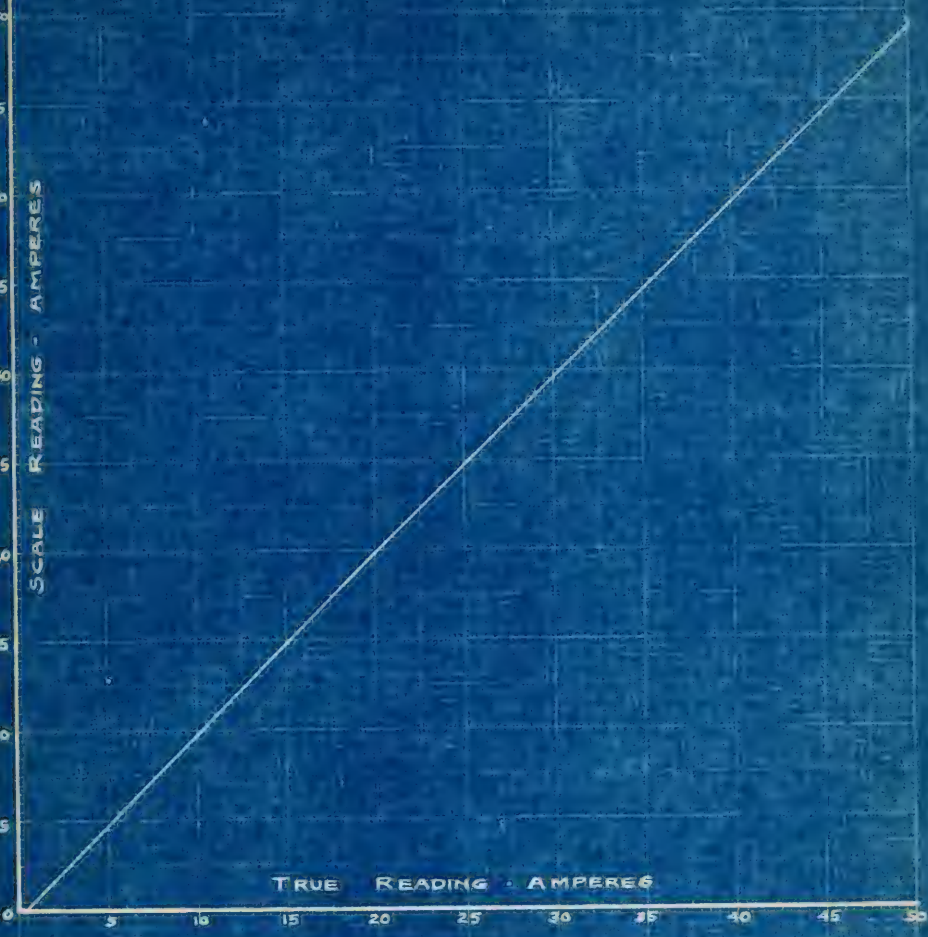


CALIBRATION CURVE FOR A (0-150)
G.E. MILLIVOLTMETER TYPE DP # 198849
WITH G.E. - 75 AMPERE SHUNT # 209592

TEST OF A COMMUTATING RECTIFIER
THESIS 1917
W.T.WATT

E.E. COURSE
C.E. STRYKER

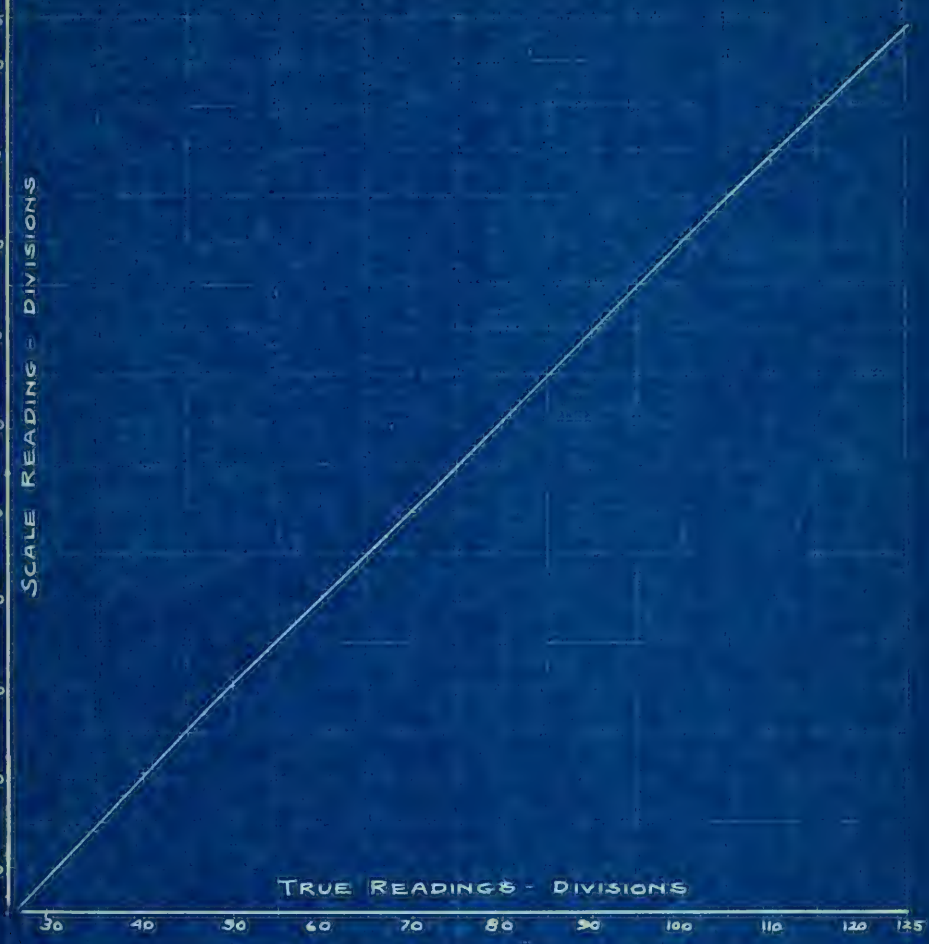
FIGURE 12



CALIBRATION CURVE FOR A (0-50)
THOMPSON A.C. AMMETER # 48835

TEST OF A COMMUTATING RECTIFIER
THESIS 1917
W.T.WATT
E.E. COURSE
C.E. STRYKER

FIGURE 13

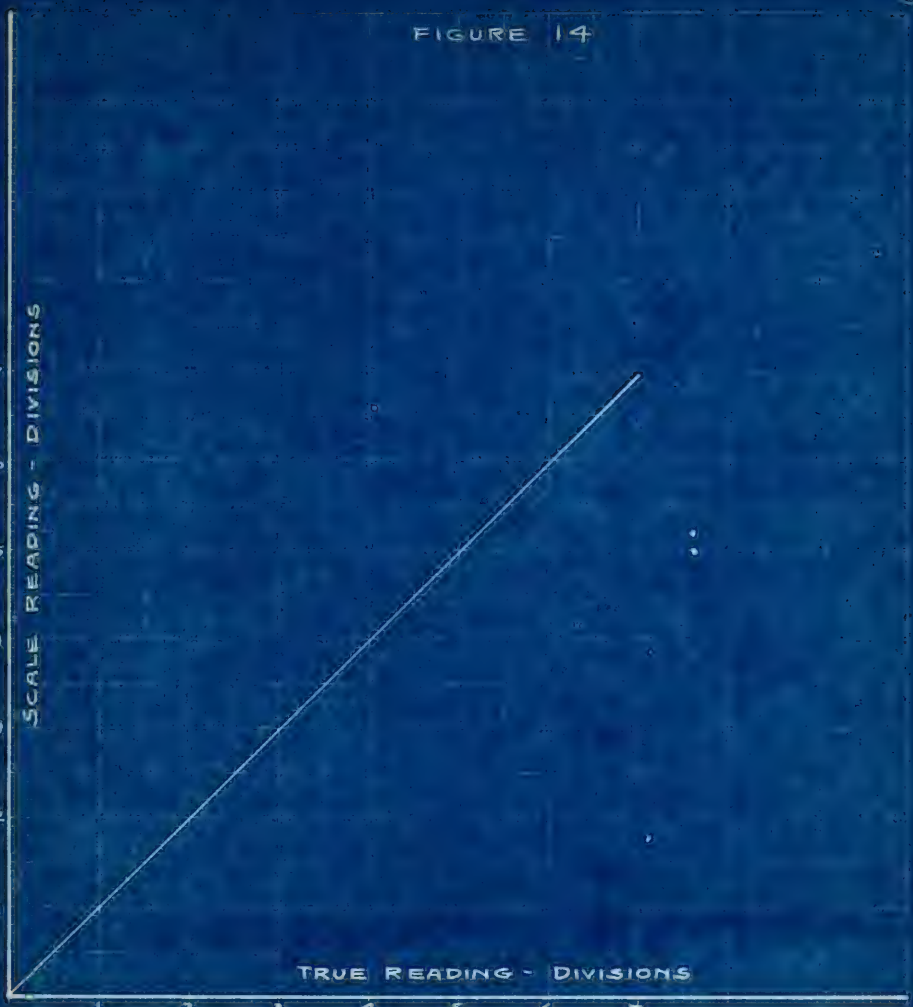


CALIBRATION OF A SIEMENS-HALSKE WATTMETER. # 079219

RANGE		SCALE READINGS
VOLTS	AMPERES	WATTS PER SCALE DIVISION
62.5	5.0	2.5
125.	5.0	5.0
250.	5.0	10.0

TEST OF A COMMUTATING RECTIFIER

FIGURE 14

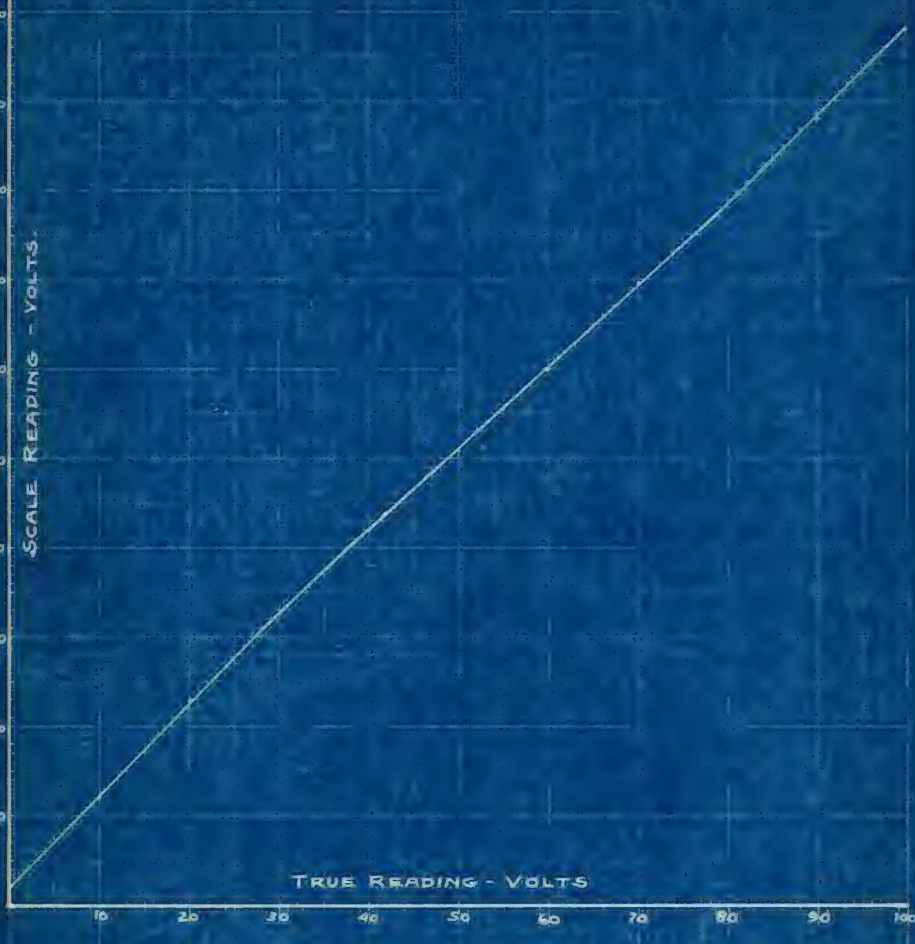


CALIBRATION CURVE FOR A WESTON WATTMETER #409 ON 50 AMP - 75 VOLT RANGE - EACH DIVISION = .5 K.W.

TEST OF A COMMUTATING RECTIFIER
THESIS 1917
W.T. WATT

E.E. COURSE
C.E. STRYKER

FIGURE 15



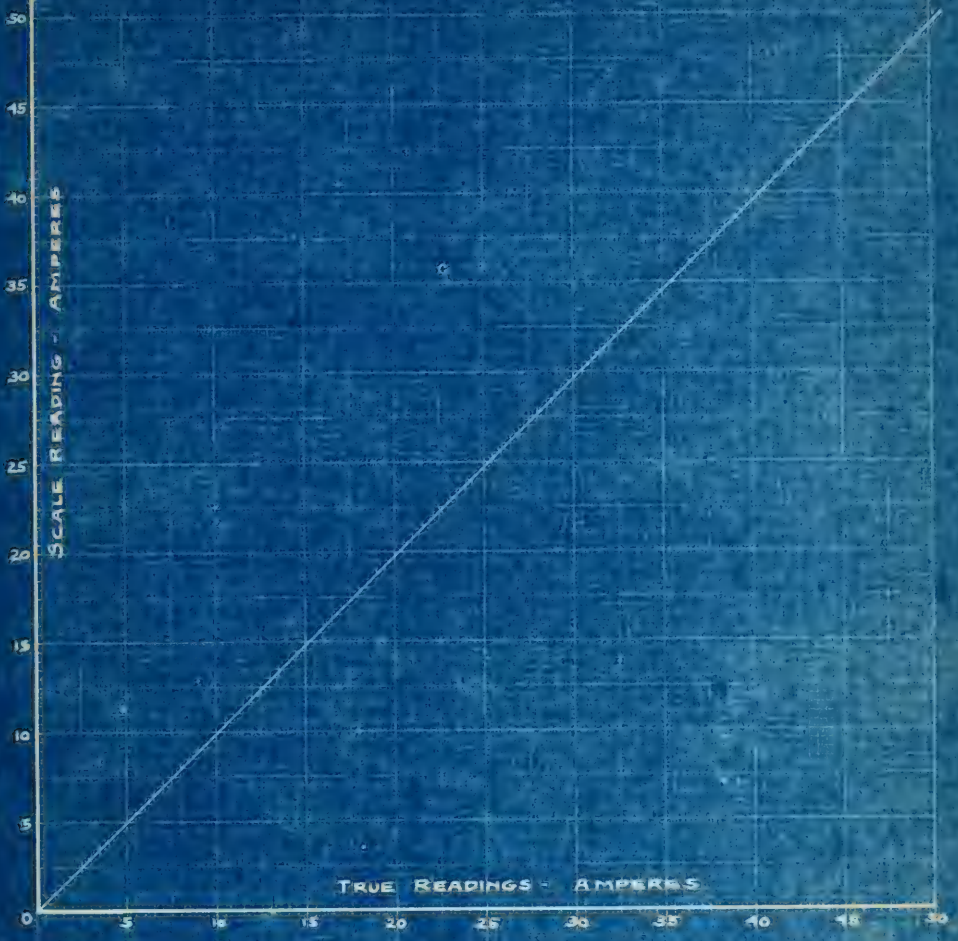
CALIBRATION CURVE FOR THE VOLTMETER ON RECTIFIER (0-110)

TEST OF A COMMUTATING RECTIFIER.

THESIS 1917
W.T. WATT

E.E. COURSE
C.E. STRYKER

FIGURE 16



CALIBRATION CURVE FOR AMMETER
ON THE RECTIFIER (0-50) D.C. #32942

TEST OF A COMMUTATING RECTIFIER
THESIS 1917
W.T.WATT

E.E. COURSE
C.E. STRIKER

TEST OF A COMMUTATING RECTIFIER.

Study of Methods and Instruments.

The current supplied by the rectifier is not continuous, but is pulsating, with a peculiar wave form. This is shown very clearly by the oscillograms. On account of this fact there is a large difference in the readings obtained from an instrument of the permanent magnet types.

From this fact there arises a difference of opinion as to whether alternating or direct current instruments should be used to measure the output. From the standpoint of the charging of the battery, the correct type of meter can be reckoned on a theoretical basis. It is known that the energy of a battery is directly proportional to the quantity of electricity that has been put in. Now, the quantity of electricity which has flowedin a circuit is measured in coulombs, which are a direct function of time and current. This means that

TEST OF A COMMUTATING RECTIFIER.

Study of Methods and Instruments.

The current supplied by the rectifier is not continuous, but is pulsating, with a regular wave form. This is shown very clearly by the oscillogrems. On account of this fact there is a large difference in the readings obtained from an instrument of the permanent magnet types.

From this fact there arises a difference of opinion as to whether alternating or direct current instruments should be used to measure the output. From the standpoint of the charging of the battery, the correct type of meter can be reckoned on a theoretical basis. It is known that the energy of a battery is directly proportional to the quantity of electricity that has been put in. Now, the quantity of electricity which has flowed in a circuit is measured in coulombs, which are a direct function of time and current. This means that

the average value of current should be used, and not the effective value, which is a function of the square of the current. From this it is apparent that, from this standpoint, the correct instrument to use is one of the permanent magnet, or familiar direct current type. As regards the correct instrument to use to measure the voltage, it was found that, due to the steadying action of the battery, the voltage is practically continuous. Due to this, the indications obtained by direct and alternating current meters are nearly the same. It is therefore immaterial which type of meter is used.

It was deemed advisable to verify the above deductions experimentally. In order to do this, the battery was placed on charge and a d.c. and a. c. ammeter and an ampere hour meter were placed in the circuit, as shown in the wiring diagram, Figure 18. A run was then

TEST OF A COMMUTATING RECTIFIER.

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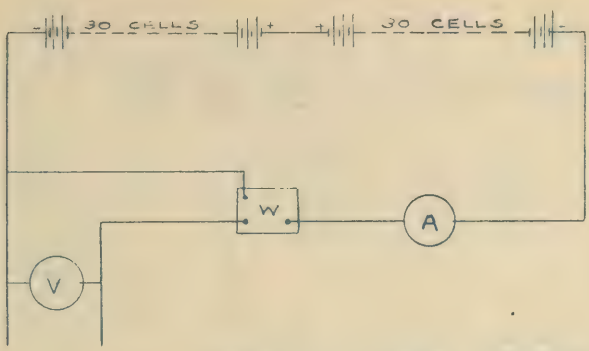
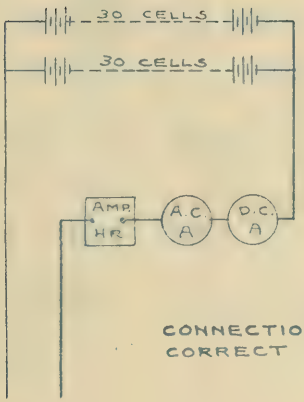
FIGURE 17



CONNECTION FOR DETERMINING CAPACITANCE OF CELLS.

FIGURE 18



CONNECTIONS FOR SELECTING CORRECT METERS TO USE.

TEST OF A COMMUTATING RECTIFIER.
THESIS 1917 E.E. COURSE
W. T. WATT C.E. STRYKER

TEST OF A COMMUTATING RECTIFIER.

TABLE 1.

Time	D.C.	A.C.	Ind. Amp.Hr.	Min.	Amp. D.C.	Hrs. A.C.
10:16	32.5	47.7	240			
				10	.503	.75
10:26	28.0	42.7				
				4	.202	.308
10:30	33.5	49.7				
				50	26.0	42.2
11:20	32.2	48.2	217			
				0	0	0
11:20	28.0	42.7	217			
				63	28.6	43.8
12:23	27.3	41.7	195			
				54	24.2	36.8
1:17	26.5	40.2	176.5			
				40	19.3	29.8
1:57	29.0	44.8	163			
				11	4.71	7.38
2:08	25.7	39.7	159.5			
				9	3.76	5.88
2:17	25.0	39.2	156.5			
				0	0	0
4:21	27.7	41.7	156.5			
				4	1.51	2.38
4:25	22.7	35.7				
				95	35.6	55.7
6:00	23.5	35.2	129			
	TOTAL		111		144.38	222.898
	CORRECTED		157.6		144.38	222.898

TEST OF A COMMUTATING RECTIFIER.

TABLE I.

Time	D.C.	A.C.	Ind. Amp.Hr.	Min.	Amp. D.C.	Hrs. A.C.
10:15	78.5	47.7	240			
				10	.803	.75
10:45	38.0	42.7				
				4	.203	.308
10:50	33.5	49.7				
				50	86.0	42.8
11:40	38.8	48.8	317			
				0	0	0
11:40	38.0	48.7	317			
				53	36.8	47.8
1:33	37.3	41.7	195			
				54	34.3	36.8
1:17	38.5	40.3	176.5			
				40	19.3	38.5
1:57	38.0	44.8	185			
				11	4.71	7.38
3:08	38.7	33.7	139.5			
				9	3.75	5.80
3:17	35.0	39.3	186.5			
				0	0	0
4:31	37.7	41.7	156.5			
				4	1.51	3.38
4:35	38.7	35.7				
				35	35.6	55.7
8:00	38.5	35.3	129			
TOTAL CORRECTED		111 137.5			144.38 144.38	338.808 338.808

made and the time noted and readings of the instruments taken, giving the data shown in Table 1.

The results of this test show conclusively that the alternating current type of instrument is not the correct one to use. The difference between the ampere hours obtained from the readings of the direct current instrument and the ampere hour meter, was in all probability due to fluctuations in the current which were not taken into account in the readings. The error of the indications of the alternating current instrument compared with the ampere hour meter was 41.3 percent of the true value.

From the standpoint of the output of the rectifier, however, since the input to the machine is measured by a wattmeter it seems only logical that the output should be measured in the same manner. The wattmeter is

TEST OF A COMMUTATING RECTIFIER.

made and the time noted and readings of the instruments taken, giving the data shown in Table I.

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From the standpoint of the output of the rectifier, however, since the input to the machine is measured by a wattmeter it seems only logical that the output should be measured in the same manner. The wattmeter is

essentially an alternating current instrument and measures the effective value and not the average. This brings us back to where we started from, so that, the efficiencies obtained by measuring the output by means of a wattmeter and direct current instruments will be both be given.

Another point to be decided is whether to charge the losses in the rheostat up to the machine or to the battery. It is apparent that were it not for the varying characteristics of the battery this rheostat would not be necessary, as it is in no way essential to the operation of the rectifier. It would seem, therefore, that the losses in the rheostat should be charged up to the battery. From another viewpoint, the economy of the device is dependent on the energy input or ampere-hour of charge, so that it would appear that all the losses connected with the operation of the rectifier should be charged up to it. General practice in the past has tended toward charging up rheostatic losses

TEST OF A COMMUTATING RECTIFIER.

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in this manner. Nevertheless, a run was made and curves plotted, charging this loss up to the battery.

Very little testing has been done in the past on this form of rectifier, so that it has been practically impossible to follow the lead of other investigators with regard to the correct methods and instruments to use. Considerable work has been done on the mercury arc rectifier, and it might be noted that general practice in testing this device has been to charge all losses to the rectifier and to use direct current meters in measuring the output.

TEST OF A COMMUTATING RECTIFIER.

in this manner. Nevertheless, a run was made and curves plotted, showing this form up to the battery.

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TEST OF A COMMUTATING RECTIFIER.

OSCILLOGRAMS.

A very important feature of this report is the analysis of the phase relations and wave forms of the various currents and e.m.f.'s, concerned in operation of the rectifier. These oscillograms are photographs of single wave forms and have been retouched only to the extent of rendering the lines clearer. No attempt has been made to preserve relative wave heights according to the actual values concerned, but rather to obtain a wave of such height that its characteristics would be most clearly shown. It was found to be practically impossible to make the axes of the two waves shown in each case coincide, so that both axes have been drawn in and labeled.

The first four oscillograms (Figures 19 to 22) show the phase relation and wave forms of the direct current output and the impressed alternating e.m.f. It might be noted here that

TEST OF A COMMUTATING RECTIFIER.

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this alternating e.m.f., which is used as a reference throughout the oscillograms, is the e.m.f. supplied to the device from the generator, and not the e.m.f. obtained from the secondary of the transformer on the rectifier. The load in these four current trials was the storage battery, the average value of current supplied to the battery varying from 7 to 35 amperes, as shown on the oscillograms. In addition to showing the wave form of the current supplied to the battery, these four curves indicate another important characteristic.

By noting the phase relation between the two waves shown, it will be seen that there is a shift in phase angle with a change in load, the current wave moving, in the diagrams, to the left with respect to the e.m.f., with an increase in load. This fact is a serious disadvantage to the satisfactory operation of the rectifier, as will be explained in a later section.

TEST OF A COMMUTATING RECTIFIER.

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TEST OF A COMMUTATING RECTIFIER.

The peculiar shape of the current wave is due to the fact that there is a dead space on the commutator between each segment, resulting in a zero value of current while the brushes are on the dead sections. The reason for these dead sections will be apparent when it is remembered that, for a large portion of the e.m.f. wave, the storage battery e.m.f. is greater than the commutated e.m.f. To prevent the backward flow of current during this portion of the wave these dead sections are inserted.

The alternating current input wave corresponding to the direct current waves shown in Figure 21 is given in Figure 23. This wave is not a sine wave, and , in addition, is out of phase with the e.m.f. wave, accounting for the low power factor of the power taken by the rectifier.

To find out the effect of substituting another load for the storage battery, a lamp rack was connected as a load, and wave forms taken. These are shown in Figure 24. Practically the only dif-

TEST OF A COMMUTATING RECTIFIER.

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To find out the effect of substituting another load for the storage battery, a lamp rack was connected as a load, and wave forms taken. These are shown in Figure 24. Practically the only dif-

ference between this current wave and the battery current wave is the flattened shape of the wave. This is probably due to the fact that the lagging effect of the battery e.m.f. was not present, allowing the current to increase more rapidly than with a battery load. It will also be noted that the wave is a little lop-sided, the side of increase (the right side) being more nearly vertical than the other side. This may be explained by the fact that the brushes cannot be placed in the exact center of the commutating position on account of the fact that the width of brushes must be provided for. The peculiar dent in the e.m.f. wave must have been caused by the sudden application of load at that point, as the machine was fed through a rather long feeder, rendering the liability of a high instantaneous drop in voltage very probable.

The remaining oscillograms show the direct e.m.f. waves obtained at the commutator under no load conditions. The e.m.f. wave when charging a

TEST OF A COMMUTATING RECTIFIER.

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battery is nearly a straight line, and when feeding a resistance load is the same as the current wave, so that their inclusion was thought unnecessary. Figure 25 shows the wave under normal conditions, illustrating the smoothing effect of the condenser, necessary to hold the relay in contact. The other curve, Figure 26, shows the effect of disconnecting the condenser, making clear the fact that the e.m.f. is very pulsating.

It is believed that the oscillograms aid very much in the correct determination of the characteristics of this device, especially as so little is known about its various features.

TEST OF A COMMUTATING RECTIFIER.

battery is nearly a straight line, and when feeding a resistance load is the same as the current wave, so that their inclusion was thought unnecessary. Figure 35 shows the wave under normal conditions, illustrating the smoothing effect of the condenser, necessary to hold the relay in contact. The other curve, Figure 36, shows the effect of disconnecting the condenser, making clear the fact that the e.m.f. is very pulsating.

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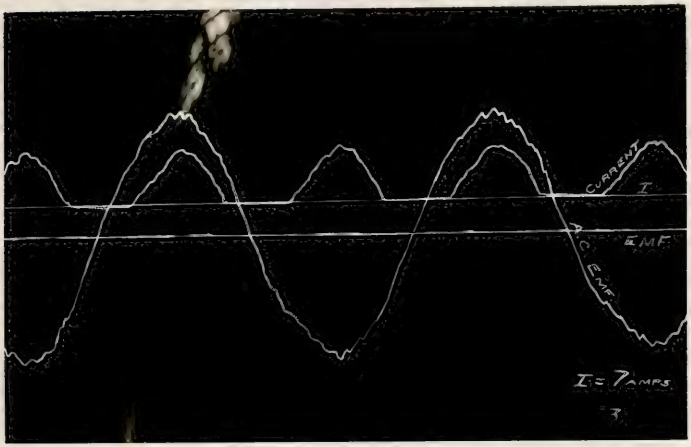
TEST OF A COMMUTATING RECTIFIER.

Figure 19.

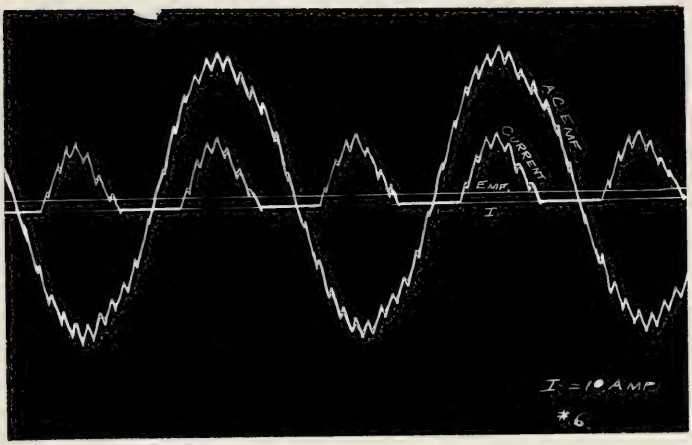


Direct Current Output Wave.

7 Ampere Storage Battery Load.

TEST OF A COMMUTATING RECTIFIER.

Figure 20.

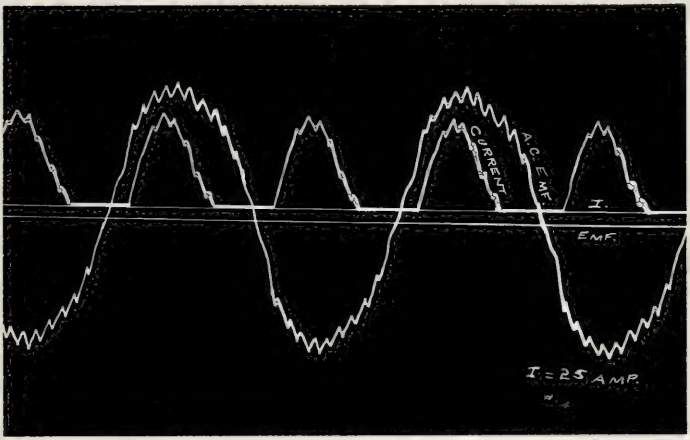


Direct Current Output Wave.

10 Ampere Storage Battery Load.

TEST OF A COMMUTATING RECTIFIER.

Figure 31.

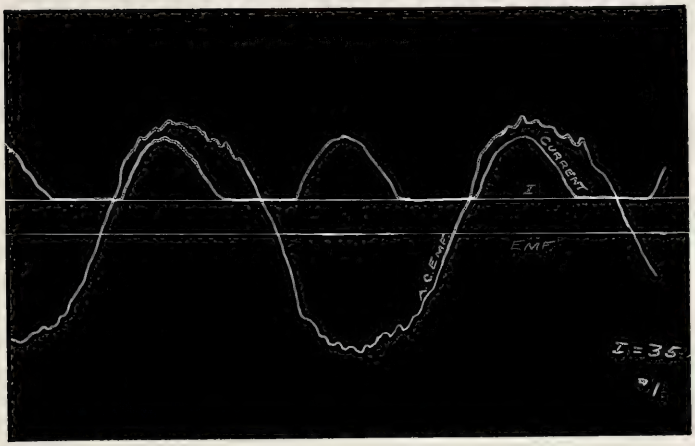


Direct Current Output Wave.

25 Ampere Storage Battery Load.

TEST OF A COMMUTATING RECTIFIER.

Figure 23.

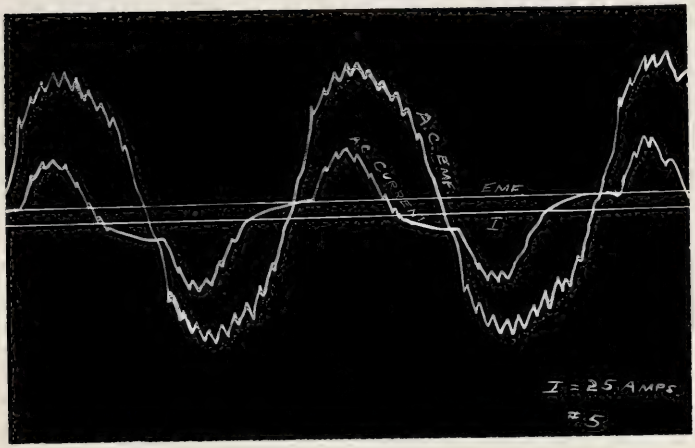


Direct Current Output Wave.

35 Ampere Storage Battery Load.

TEST OF A COMMUTATING RECTIFIER.

Figure 23.

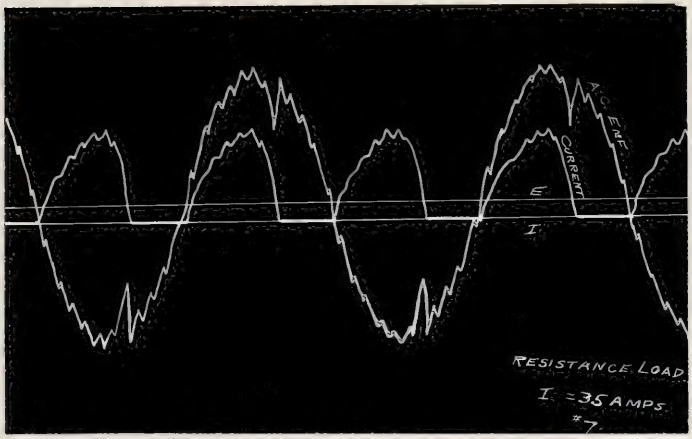


Alternating Current Input Wave.

35 Ampere Storage Battery Load.

TEST OF A COMMUTATING RECTIFIER.

FIGURE 24.

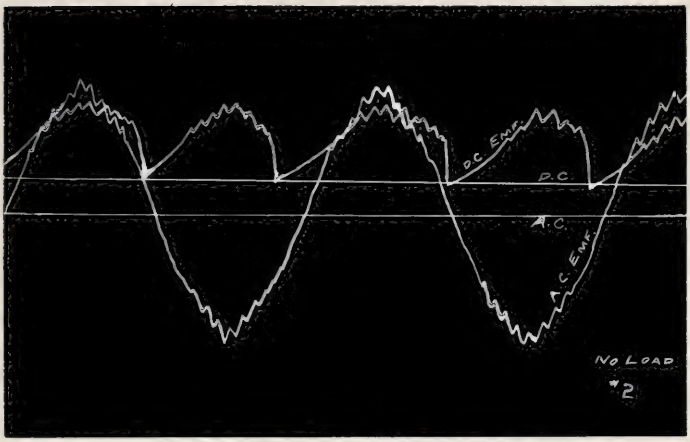


Direct Current Output Wave.

35 Ampere Resistance Load.

TEST OF A COMMUTATING RECTIFIER.

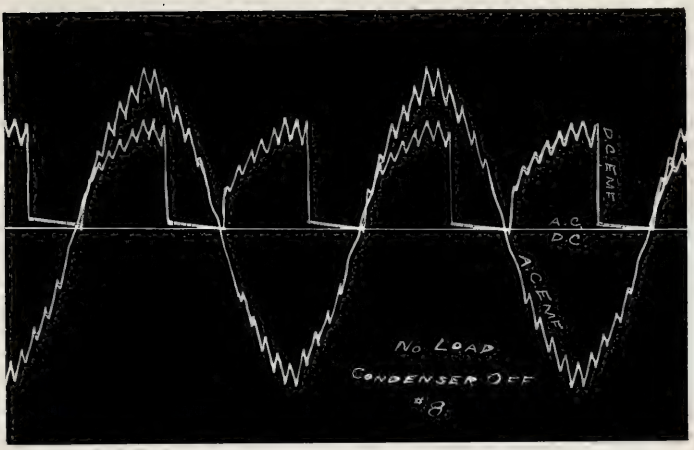
Figure 35.



Direct E.M.F. Wave, No Load.

TEST OF A COMMUTATING RECTIFIER.

Figure 26.



Direct E. M. F. Wave

No Load - Condenser Disconnected.

TEST OF A COMMUTATING RECTIFIER.

DETERMINATION OF OPERATING CHARACTERISTICS.

The greatest difficulty in the way of obtaining satisfactory operation was the necessity of changing the brush position with changes in load. While the sparking resulting from leaving the brushes in one position for all loads is not serious, still, if it is present, operation can not be considered perfect. It is evident that the motor will "follow" the impressed e.m.f. Now, the correct brush position "follows" the current output, so that it will be clear that, if the phase relation between the output current and the impressed e.m.f. be changed, a shift in the correct brush position will be inevitable. The only way to avoid trouble from this source is to eliminate this shifting of phase.

The first cause of this shifting suspected was the change in phase angle, with load, of the primary and secondary currents of the transformer. However, it was not thought likely that this displacement alone would be sufficient to cause the

TEST OF A COMMUTATING REGULATOR.

DETERMINATION OF OPERATING CHARACTERISTICS.

The greatest difficulty in the way of obtaining satisfactory operation was the necessity of changing the brush position with changes in load. While the sparking resulting from leaving the brushes in one position for all loads is not serious, still, if it is present, operation can not be considered perfect. It is evident that the motor will "follow" the impressed e.m.f. Now, the correct brush position "follows" the current output, so that it will be clear that, if the phase relation between the output current and the impressed e.m.f. be changed, a shift in the correct brush position will be inevitable. The only way to avoid trouble from this source is to eliminate this shifting of phase.

The first means of this shifting suggested was the change in phase angle, with load, of the primary and secondary currents of the transformer. However, it was not thought likely that this displacement alone would be sufficient to cause the

shift obtained, so that the investigation was extended. As the rehostat used for regulating the rate of charge was constructed of iron, it was considered possible that inductance might be present. Tests were made by applying an alternating current and measuring the input watts and volt-amperes. They were found to differ slightly, indicating the presence of inductance.

As a check on this result, a non-inductive resistance load was used of such resistance that, under a current of about 25 amperes , the drop over it approximated that over the storage battery. The current was then varied by inserting and withdrawing the rheostat on the rectifier. The results of this test were : the correct brush position did not alter perceptibly with a change in load from no load to 200% overload, nor with all or none of the supposed inductive rheostat in circuit. This test showed conclusively that neither the rheostat nor the phase displacement

TEST OF A COMMUTATING RECTIFIER.

in the transformer was the cause of the trouble.

The possibility of capacitance in the battery was next taken up. The battery was cut into the two sections and connected to an A.C. source, as shown in Figure 17, and a 30 Cycle current run through it. The results obtained were, that for a current of 41 amperes, the power input was 353.75 watts and the apparent input was 370.87 volt-amperes. This indicates the presence of some capacitance. When being charged, the battery sections are connected in parallel, instead of in series, making the effective capacitance four times as great as obtained in the test. No definite figures as to the actual capacitance were obtained,as the battery is a very leaky condenser, causing the introduction of several unknown veriables into its capacity equation, making the calculation of its absolute capacitance impracticable. It seems probable, that this effect

TEST OF A CONDUCTING ANCHISTIRE.

The possibility of capacitance in the battery was next taken up. The battery was cut into the two sections and connected to an A.C. source, as shown in Figure 17, and a 30 Cycle current run through it. The results obtained were, that for a current of 11 amperes, the power input was 385.75 watts and the apparent input was 770.87 volt-amperes. This indicates the presence of some capacitance. When being charged, the battery sections are connected in parallel, instead of in series, making the effective capacitance four times as great as obtained in the test. No definite figure as to the actual capacitance were obtained, as the battery is a very leaky condenser, causing the introduction of several unknown variables into its capacity equation, making the calculation of its absolute capacitance impracticable. It seems probable, that this effect

is the cause of the shifting of brush position, although there certainly is room for future investigation in this direction.

Another source of trouble in operation, which although largely imaginary, has caused many inquiries from garage men, is the blackening of the collector rings. After being operated for some time, black spots appear on the collector rings, two on each ring, diametrically opposite each other, those on one ring being in quadrature with those on the other ring. Close inspection shows that they extend over only those positions of the collector rings where current is flowing from the brush to the ring. The fact that soft brushes are used, coupled with the heated condition of the collector rings, indicates that this blackening was probably due to a plating action between the brushes and the rings.

As to the heating of the commutator and

TEST OF A COMMUTATING RECTIFIER.

As to the heating of the commutator and rings.

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The fact that soft brushes are used, coupled current is flowing from the brush to the ring. these positions of the collector rings where insulation above that they extend over only quadrature with those on the other ring. Those opposite each other, those on one ring being in collector rings, two on each ring, diametrically arated for some time, black spots appear on the ening of the collector rings. After being op- many inquiries from large men, in the affir- which although largely imaginary, has caused

Another source of trouble in operation, vestigation in this direction.

although there certainly is room for future in- is the cause of the shifting of brush position,

collector rings, it might be said that this is not serious, it being possible to lay the hand on the commutator after several hours running, during which time it would seem that stable conditions would have resulted.

The automatic features of the rectifier were tried out to determine their reliability. The reverse current relay was found to be thoroughly adequate, as it was possible to short circuit the incoming line without causing any detrimental sparking at the commutator or an appreciable discharge of the battery to take place. The polarity selection was perfect; in not one instance did the relay fail to come in at the correct polarity. The effect of reducing the line voltage was tried, and it was found that the reverse current feature opened the circuit when the alternating voltage had dropped to about 170. On again increasing the voltage, the rectifier did not come in until a voltage of about 210 had

TEST OF A COMMUTATING RECTIFIER.

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The automatic and protective features seem to meet all requirements, and, as they need no adjustment, it seems reasonable to believe that they will give reliable service, even in the hands of unskilled men.

TEST OF A COMMUTATING RECTIFIER.

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The automatic and protective features seem to meet all requirements, and, as they need no adjustment, it seems reasonable to believe that they will give reliable service, even in the hands of unskilled men.

TEST OF A COMMUTATING RECTIFIER.

DETERMINATION OF EFFICIENCY.

Three efficiency runs were made, one in which the load was the battery and the rheostatic losses charged to the rectifier, another in which the load was the battery and the rheostatic losses were charged to the battery, and the third, in which the load was a resistance and the rheostat cut out of circuit. The connection for the resistance runs are shown in Figure 27.

In taking efficiency runs, the load was adjusted to the desired value and a stable condition obtained. Five sets of readings were then taken at intervals of about one minute and their averages taken as a correct value.

In the first run the rheostatic losses were charged to the rectifier, the meters measuring the output being connected, as shown by the solid lines. The data obtained is given in Table 2 and the resulting curves are shown in Figure 28. It will be noted that the

TEST OF A COMMUTATING RECTIFIER.

DETERMINATION OF EFFICIENCY.

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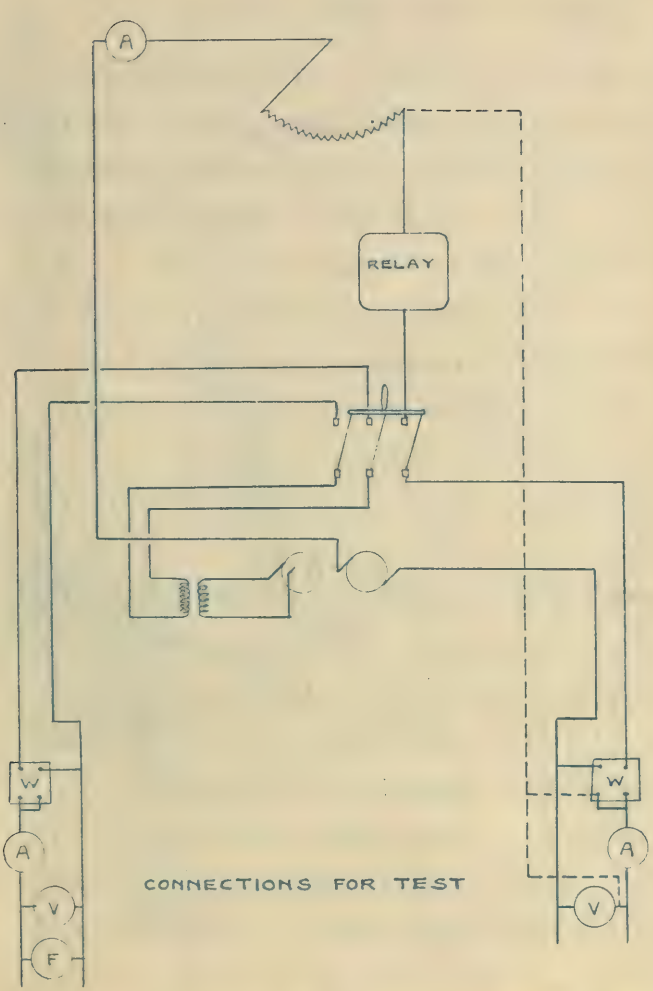
FIGURE 27



CONNECTIONS FOR TEST

TEST OF A COMMUTATING RECTIFIER
THESIS 1917
W. T. WATT
E.E. COURSE
C. E. STRYKER

efficiencies obtained by the two different methods and instruments are nearly alike in this run, indicating that the form factor of this wave is practically unity.

The second run is the same as the first except that the rheostatic losses are charged to the battery, the meters measuring the output being connected as shown in Figure 27 by the dotted lines. The efficiencies obtained in this run are of course higher than they were in the first, while the difference between the values given by the two methods is greater, due to a change in the e.m.f. wave form. The results obtained are given in Table 3 and the curves in Figure 29.

In the third run a lamp rack was used as a load. The connections were the same as in Figure 27 except that the rheostat was cut out of circuit. The load was varied and a set of

TEST OF A COMMUTATING RECTIFIER.

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In the third run a lamp rack was used as a load. The connections were the same as in Figure 27 except that the rheostat was cut out of circuit. The load was varied and a set of

readings obtained for each load. The averages of these sets are given in Table 4 and the curves in Figure 30. There is a larger difference in the efficiencies given by the two methods, due to the change in the form of e.m.f. wave, as shown by the oscillograms.

The losses in the rectifier itself may be divided as follows : the losses in the transformer, the power consumed by the relay coils, the power consumed by the motor driving the commutator, and the losses incurred in commutation.

The efficiency of the transformer was calculated as recommended in the standardization rules of the American Institute of Electrical Engineers, the results being given in Table 5 and Figure 31. The no load losses have been determined and subdivided as given in Table 5. The losses in the relay coils and in the motor will of course remain constant at all loads.The remaining losses in the machine are those due to sparking and eddy currents in the commutator.

TEST OF A COMMUTATING RECTIFIER.

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TEST OF A COMMUTATING RECTIFIER.

TABLE 2.

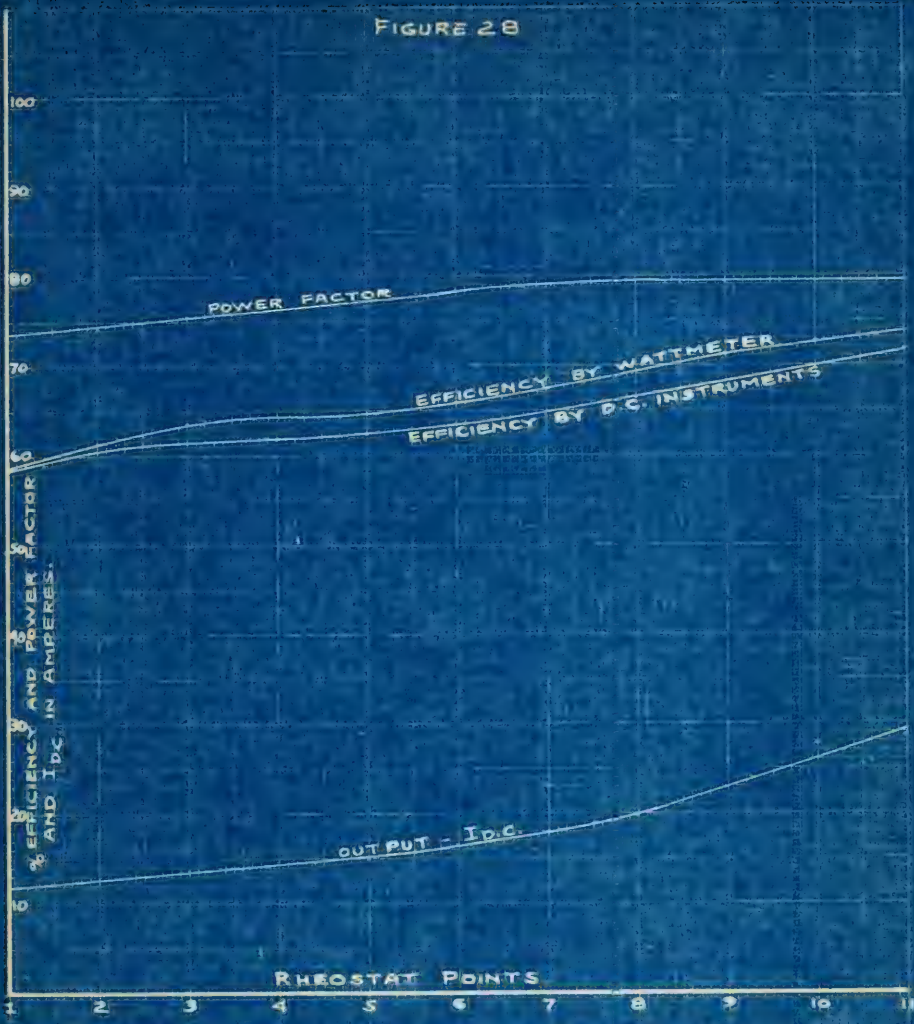
Rheostat Losses Charged to Rectifier.

Rheo. Pt.	K.W. a.c.	I a.c.	V d.c.	K.W. d.c.	% Eff. Watt-meter.	% Eff. by D.C. Insts.
1	1.383	8.30	70.1	.81	58.5	58.3
2	1.400	8.71	70.4	.855	61.0	60.3
3	1.584	9.58	70.6	1.060	64.1	61.8
4	1.655	9.80	70.8	1.060	64.1	61.8
5	1.707	10.18	70.8	1.098	64.3	62.2
6	1.860	10.82	71.4	1.223	65.8	63.5
7	1.991	11.55	71.6	1.340	67.3	64.8
8	2.156	12.30	72.2	1.485	69.0	66.3
9	2.435	13.95	72.6	1.730	71.1	68.4
10	2.649	15.15	73.1	1.931	72.9	76.5
11	2.920	16.72	73.4	2.208	73.7	71.6

A.C. Voltage - 220

Frequency - 60 Cycles

FIGURE 28



TEST OF A 30 AMP. - 220 VOLT - STAHL RECTIFIER
RHEOSTAT LOSSES CHARGED TO RECTIFIER

TEST OF A COMMUTATING RECTIFIER
THESIS 1917 E.E. COURSE
W.T. WATT C.E. STRYKER

TEST OF A COMMUTATING RECTIFIER.

TABLE 3.

Rheo. Pt.	K.W. a.c.	I a.c.	V a.c.	K.W. d.c.	% Eff. by Watt-meter.	% Eff. by D.C. Insts.
1	1.48	9.3	78.7	1.18	79.6	67.1
2	1.56	9.5	78.5	1.26	80.2	67.1
3	1.69	10.3	78.3	1.41	83.3	69.5
4	1.79	10.6	78.1	1.45	80.9	69.1
5	1.89	11.1	77.9	1.55	82.1	69.7
6	2.09	11.9	77.6	2.02	83.5	70.0
7	2.40	13.6	77.6	1.72	82.4	71.3
8	2.75	15.2	77.5	2.26	82.3	71.7
9	3.06	17.0	76.3	2.54	83.2	73.7
10	3.40	18.6	75.4	2.78	81.8	73.9
11	3.69	20.4	73.8	3.06	82.8	74.2

A.C. Voltage - 220

Frequency - 60 Cycles.

Rheostatic Losses Charged to Battery.

TEST OF A COMMUTATING RECTIFIER.

Rheostatic Losses Charged to Battery.

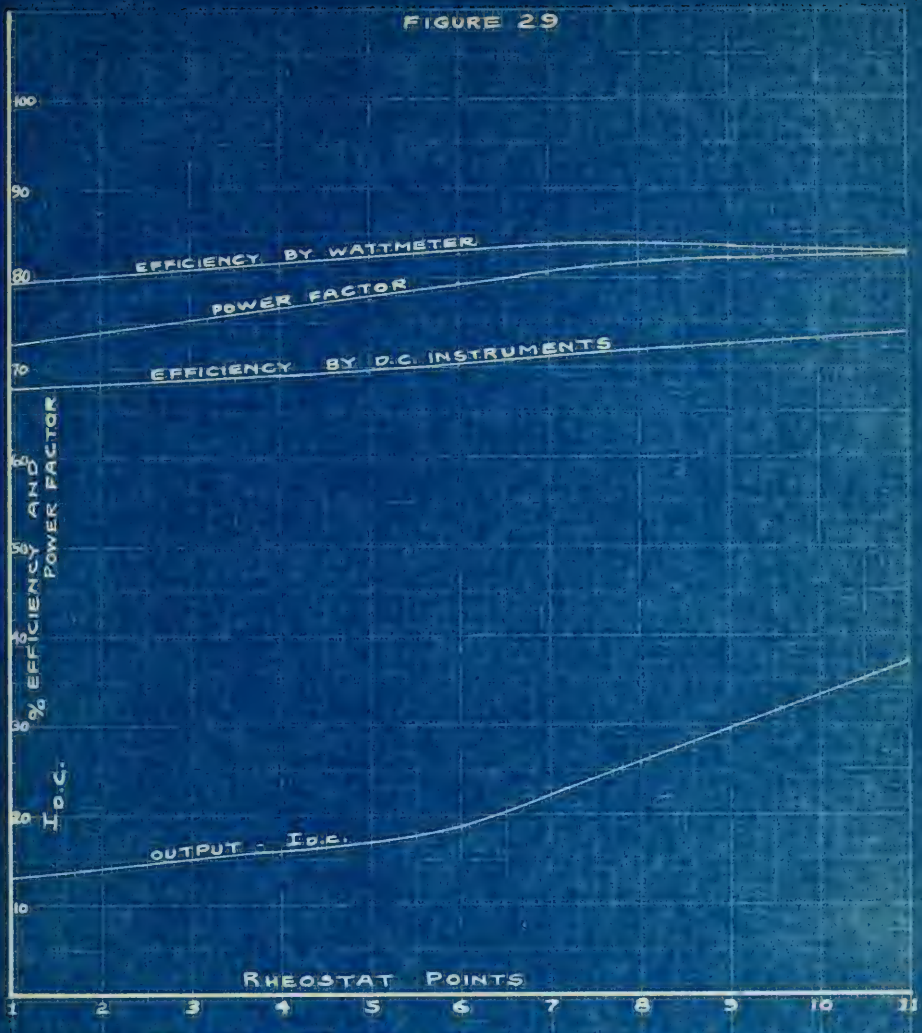
Frequency - 60 Cycles.

A.C. Voltage - 220

TABLE 3.

Load. Amps.	K.W. a.c.	I a.c.	V a.c.	K.W. d.c.	% Eff. by Watt-meter.	% Eff. by D.C. Insts.
1	1.48	9.3	78.7	1.13	76.6	67.1
2	1.56	9.5	78.5	1.26	80.3	67.1
3	1.69	10.3	78.3	1.41	83.3	69.5
4	1.79	10.6	78.1	1.46	80.9	69.1
5	1.89	11.1	77.9	1.55	82.1	69.7
6	2.09	11.9	77.6	2.03	83.5	70.0
7	2.40	13.6	77.6	1.73	82.4	71.3
8	2.75	15.8	77.5	2.26	82.3	71.7
9	3.06	17.0	76.3	2.54	83.3	72.7
10	3.40	18.6	75.4	2.78	81.8	72.9
11	3.69	20.4	73.8	3.06	82.8	74.3

FIGURE 29



TEST OF 30 AMP. - 220 VOLT - STAHL RECTIFIER
RHEOSTAT LOSSES CHARGED TO BATTERY.

TEST OF A COMMUTATING RECTIFIER
THESIS 1917 E.E. COURSE
W.T. WATT C.E. STRYKER

TEST OF A COMMUTATING RECTIFIER.

TABLE 4

Resistance Load, Rheostat cut out of circuit.

K.W. a.c.	I a.c.	I d.c.	V d.c.	K.W. d.c.	% Eff. by Watt-meter.	% Eff. by D.C. Insts.
.67	5.9	5.0	40.8	.43	64.2	30.5
1.098	8.3	10.0	40.9	.85	77.5	37.2
1.567	10.5	15.0	40.0	1.35	79.8	38.3
1.973	12.65	20.0	39.1	1.62	82.1	39.6
2.412	15.3	25.0	38.8	2.04	84.6	40.2
2.826	17.6	30.0	38.2	2.36	82.4	40.5
3.010	18.4	32.5	37.9	2.56	85.0	41.0

Voltage - 220

Frequency - 60 Cycles

TEST OF A COMMUTATING RECTIFIER.

TABLE 4

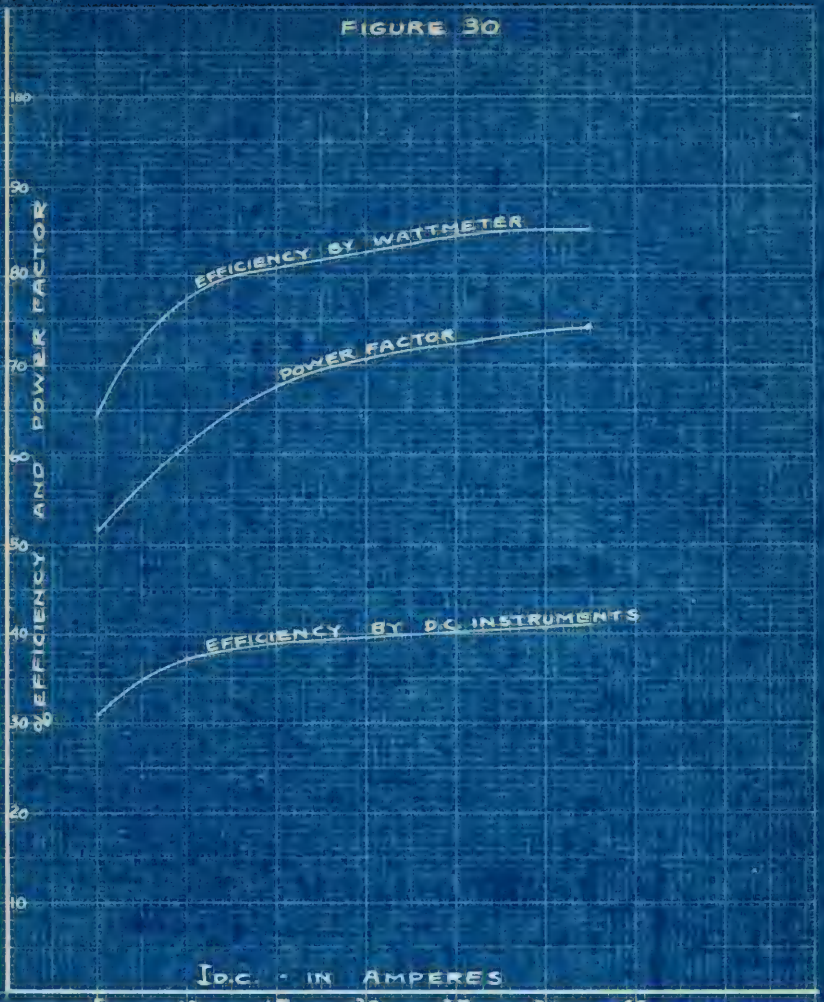
Resistance Load, Rheostat cut out of circuit.

K.W. a.c.	I a.c.	I d.c.	V d.c.	K.W. d.c.	% Eff. by Watt-meter.	D.C. Inste.
.87	5.9	5.0	40.8	.43	64.2	30.5
1.068	8.3	10.0	40.9	.85	77.5	37.2
1.567	10.5	15.0	40.0	1.25	79.8	38.3
1.973	13.65	20.0	39.1	1.62	82.1	39.6
2.412	15.3	25.0	38.8	2.04	84.6	40.2
2.886	17.6	30.0	38.2	2.36	82.4	40.5
3.010	18.4	32.5	37.9	2.56	85.0	41.0

Voltage - 220

Frequency - 60 Cycles

FIGURE 30



TEST OF A 30 AMP.- 220 VOLT - STAHL RECTIFIER WITH RESISTANCE LOAD ADD RHEOSTAT CUT OUT.

TEST OF A COMMUTATING RECTIFIER
THESIS 1917 E.E. COURSE
W.T. WATT C.E. STRYKER

TEST OF A COMMUTATING RECTIFIER.

TABLE 5.

Efficiency of Transformer.

I secondary	W copper	W total	% Eff.
5	3.5	32.5	96.0
10	7.5	37.5	96.45
15	13.5	43.5	96.5
20	23.5	53.5	96.55
25	27.5	57.5	97.0
30	41.2	71.2	96.8
35	48.9	78.9	96.9
40	67.4	97.4	96.95
45	83.6	113.6	96.8
50	100.0	130.0	96.7

Ratio of Transformation - 220:75.6

Core Loss at 220 Volts, 60 Cycles - 30 Watts.

RECTIFIER NO LOAD LOSSES

Total Loss	257 Watts
Motor Input	203 Watts
Transformer Loss	30 Watts
Relay Coil Loss	24 Watts

TEST OF A COMMUTATING RECTIFIER.

TABLE 5.

Efficiency of Transformer.

I secondary	W copper	W total	% Eff.
5	3.5	33.5	96.0
10	7.5	37.5	96.45
15	13.5	43.5	96.5
20	23.5	53.5	96.55
25	37.5	57.5	97.0
30	41.3	71.3	96.8
35	48.9	78.9	96.9
40	67.4	97.4	96.95
45	83.6	113.6	96.8
50	100.0	130.0	96.7

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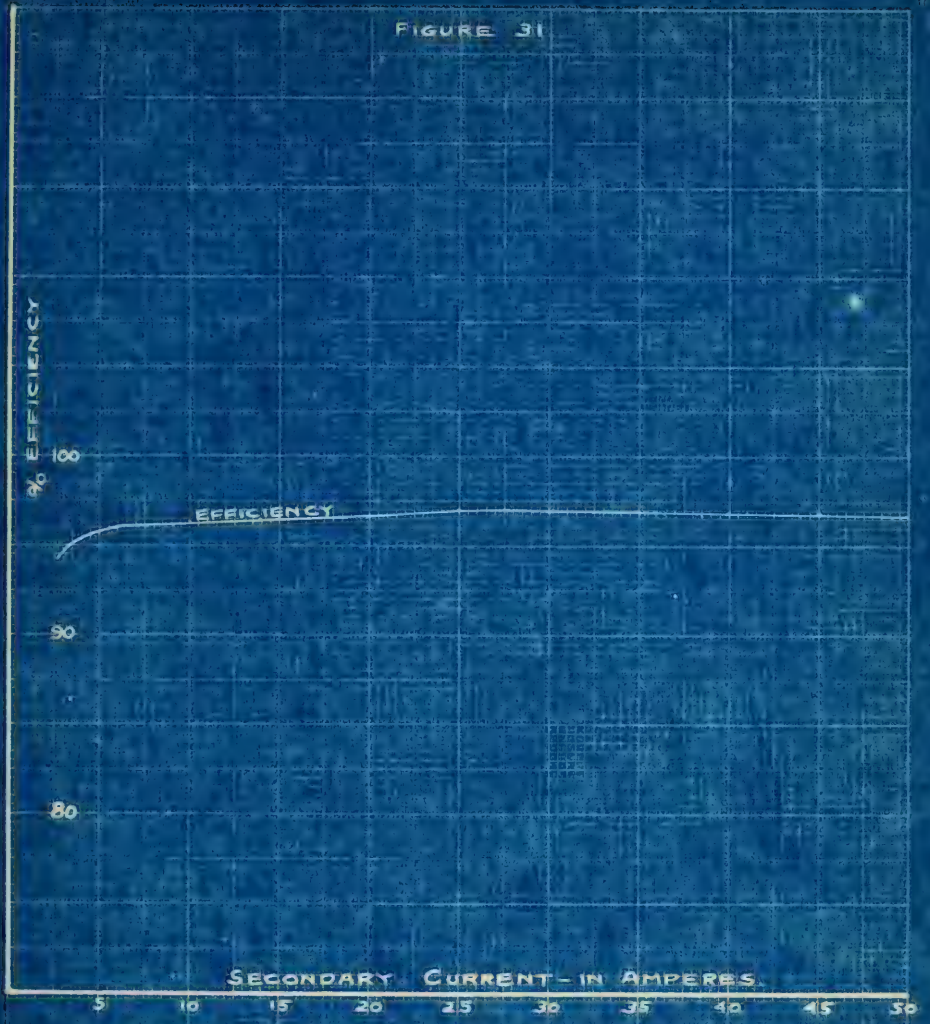
FIGURE 31



EFFICIENCY TEST OF TRANSFORMER ON RECTIFIER

TEST OF A COMMUTATING RECTIFIER

THESIS 1917
W. T. WATT

E.E. COURSE
C.E. STRYKER

TEST OF A COMMUTATING RECTIFIER.

Commercial Applicability.

The tests made show that the efficiency of this device runs in the vicinity of 75%. There is no apparent reason why this efficiency should not be maintained during the entire life of the rectifier. The only active competitor in this field is the Mercury Arc Rectifier. The average overall efficiency of this type of device is a little better than 50%. This efficiency drops off with the age of the bulb.

The initial cost of the Mercury Arc Rectifier is from 25 to 50% in excess of the cost of a Commutating Rectifier of the same capacity. In addition, there is nothing about the Commutating Rectifier to require periodic renewal, while in the Mercury Arc Rectifier the bulbs must be renewed after a certain number of hours of life, at a cost per bulb somewhat in excess of ten dollars.

The Mercury Arc Rectifier is a device of a somewhat complicated nature and requires, for the

TEST OF A COMMUTATING RECTIFIER.

Commercial Applicability.

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The initial cost of the Mercury Arc Rectifier is from 25 to 50% in excess of the cost of a Commutating Rectifier of the same capacity. In addition, there is nothing about the Commutating Rectifier to require periodic renewal, while in the Mercury Arc Rectifier the bulbs must be renewed after a certain number of hours of life, at a cost per bulb somewhat in excess of ten dollars.

The Mercury Arc Rectifier is a device of somewhat complicated nature and requires, for the

most efficient use, the attention of a skilled operator. Furthermore, there is a fragile bulb to be taken into account. The Commutating Rectifier is rather simple and after once being adjusted may be trusted to the care of the average garage attendant. This ruggedness also tends toward an increased reliability of service on account of less frequent shut-downs for repairs.

The particular type of rectifier tested in this report was entirely automatic in operation, rendering it impossible to be damaged by temporary line shut-downs, and so forth. It also possessed the very valuable feature of coming back onto the line as soon as service was restored. In contrast to this, a certain load must be carried at all times on the Mercury Arc Rectifier, in order to maintain the arc, and the rectifier must be started by hand after each shut-down.

At the present time, there is a demand for

TEXT OF A COMMUTATING RECTIFIER.

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take the air, and the rectifier must be started by times on the Mercury Arc Rectifier in order to main- to this, a certain load must be carried at all line as soon as service was restored. In contrast the very valuable feature of coming back onto the line shut-down, and so forth. It also possessed rendering it impossible to be damaged by temporary in this report was entirely automatic in operation,

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tends toward an increased reliability of ser- average factor attendant. This ruggedness also adjusted may be trusted to the care of the Rectifier is rather simple and after once being built to be taken into account. The Commutating operator. Furthermore, there is a fragile most efficient use, the attention of a skilled

TEST OF A COMMUTATING RECTIFIER.

a rectifier of moderate size in only two fields, namely, storage battery charging and motion picture arc work. The rectifier tested was designed especially for charging storage batteries and has proved to be satisfactory for that work. In the motion picture field, however, it has not been so successful. The two principal objections to the use of alternating current in the motion picture arc are - the poor light obtained, and the noise. If a rectifier of the commutating type is used, an excellent light is obtained, but the noise is accentuated on account of the fact that the current supplied by the rectifier changes in value even more rapidly than the alternating current. This can be clearly seen from the wave form shown in Fig. 24. Developments are now under way to perfect a device of this kind so that the fluctuations will be greatly diminished.

Taking into consideration all of the facts, it would seem that there is a large opening for a rectifier of the commutating type.

TEST OF A COMMUTATING RECTIFIER.

a rectifier of moderate size in only two fields, namely, storage battery charging and motion picture are work. The rectifier tested was designed especially for charging storage batteries and has proved to be satisfactory for that work. In the motion picture field, however, it has not been so successful. The two principal objections to the use of alternating current in the motion picture are are - the poor light obtained, and the noise. If a rectifier of the commutating type is used, an excellent light is obtained, but the noise is accentuated on account of the fact that the current supplied by the rectifier changes in value even more rapidly than the alternating current. This can be clearly seen from the wave form shown in Fig. 24. Developments are now under way to perfect a device of this kind so that the fluctuations will be greatly diminished.

Taking into consideration all of the tests, it would seem that there is a large opening for a rectifier of the commutating type.

TEST OF A COMMUTATING RECTIFIER.

APPENDIX.

BIBLIOGRAPHY.

1. Burgess - "Rectifiers" -
Electrical Review, February 27, 1904.

2. N. G. Meade -"The Mercury Rectifier"
Power - November 2, 1909.

3. Yasudus Sakai - "Application of the Oscillograph in Studying the Operation of Rectifiers".
Electrical Journal - March, 1910.

4. Morecroft - "Laboratory Manual of Alternating Currents".

5. Standard Handbook for Electrical Engineers.

TYPE OF A COMMUTATING RECTIFIER.

APPENDIX.

BIBLIOGRAPHY.

1. Burgess - "Rectifiers" -

Electrical Review, February 27, 1904.

2. K. P. Wedde -"The Mercury Rectifier"

Power - November 3, 1903.

3. Taunton Smart - "Application of the

Oscillograph in Studying the Operation

of Rectifiers".

Electrical Journal - March, 1910.

4. Moreycroft - "Laboratory Manual of Alternating Currents".

5. Standard Handbook for Electrical Engineers.